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Principal Insect Enemies

OF THE

SUGAR BEET

IN THE TERRITORIES SERVED BY

The Great Western Sugar Company

BY

ASA C. MAXSON

In Charge, Experimental Department

Although there are many avenues to wisdom, books remain the primary source.

ELMO ROPER

A Gift to

The Colorado College

by

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Principal Insect Enemies

OF THE

SUGAR BEET

IN THE TERRITORIES SERVED BY

The Great Western Sugar Company

BY

ASA C. MAXSON

In Charge, Experimental Department

Published by
AGRICULTURAL DEPARTMENT
THE GREAT WESTERN SUGAR COMPANY
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PREFACE

Some damage is done by some pest somewhere every year, causing some loss to individual farmers. Fortunately, we have been free so far from pests damaging very large areas in any one year, and it is confidently hoped that this will always be the case in the territory served by this Company. Nevertheless, it seems wise to have on hand all the information necessary to enable growers to apply proper measures in case of emergency.

There are available a number of bulletins and books published by the Department of Agriculture, Agricultural Colleges and others, dealing with insect pests damaging to sugar beets, but it has been thought of interest and value to beet growers to have this information presented in one book and with due regard to local conditions.

While it is hoped that this Bulletin will be of valuable assistance to the grower of sugar beets by presenting the best known methods of preventing injury and controlling insects which damage this crop, it seems desirable to impress upon him the fact that there is no magical method, no patent medicine, which can be quickly and easily applied.

Good farming, as taught by local experience, practiced consistently every year, will produce bigger yields of beets and minimize the damage done by insects or beet diseases.

For the benefit of those wishing to study the subject more completely, scientific names of insects, other invertebrate animals, and plants discussed, have been given in the Appendix, pages 138 to 146, together with credit for determination. Free use has been made of the literature of beet insects and credit given where it has been quoted.

This Bulletin has been prepared by Mr. A. C. Maxson, Entomologist in charge of the Company's Experimental Farm at Longmont, Colorado.

Credit is due Miss Caroline M. Preston for reproducing the insects for the colored plates.

THE GREAT WESTERN SUGAR COMPANY

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INTRODUCTION

The impression may be gained that the sugar beet is especially liable to insect injury because of the bringing together of so much on the subject. However, this is not the case. A study of crop insects shows that most crops have an equal number of insect enemies and many have more. It should be emphasized that everything known to good farming practice in beet culture, such as rotation of crops, manuring, clean culture, and timeliness of plowing and irrigating, tends to minimize damage by insects.

OUTLINE OF THE BULLETIN

By knowing in advance the structural plan of the Bulletin, reference can more readily be made to any desired part. Hence an outline is given on page 3. Furthermore, the use of this Outline in conjunction with the "Key for Determining Insect Injury to Sugar Beets" (pages 5 to 8) may aid in identifying insects. For example, if it is known that damage is being done to the leaves of the beets and that the insects causing it are "Biting" insects, and if it is known that they are not beetles or grasshoppers, then it can, for practical purposes, be concluded that the damage is being caused by either leaf-miners or caterpillars, and by referring to the text cited, a conclusion can in most cases be drawn regarding the particular insect causing the damage. **If one of the suspected insects has been caught, the Colored Plates (See pages 11 to 27) will greatly facilitate its identification.**

KEY FOR DETERMINING INSECT INJURY TO SUGAR BEETS

In order to facilitate the use of this Bulletin for reference purposes, a short "Key for Determining Insect Injury to Sugar Beets" has been constructed. (See pages 5 to 8.) If the nature of the insect damage is known, reference to this "Key" should enable one to determine the general class of insect doing the damage, if not the particular insect. By looking up the descriptive pages cited in the "Key", **and by checking the Colored Plates against the suspected insect,** if one has been caught, a reasonably strong case can probably be established.

COLORED PLATES

It took the artist three seasons to complete the drawings from which the Colored Plates were made. Every insect was drawn directly from a live specimen, and the form and colors are true to life.

Some of these colored pictures were enlarged. In nearly all such cases a small black and white outline at the left or right of the colored picture shows the natural size of the specimen. The exceptions are clearly noted on the title pages.

Pictures as well prepared as these carry descriptions much more quickly and accurately than words, especially to persons not trained to think in entomological terms.

The main purpose of all this care in preparing these Colored Plates is to enable the reader to identify, in the easiest and most positive manner possible, any specimens he may have procured.

The title page opposite each plate gives the name of each specimen and indicates the pages of the Bulletin on which it is discussed.

Additional help in locating the pages on which any individual insect is discussed may be had from the Outline of the Bulletin (page 3), the "Key for Determining Insect Injury to Sugar Beets" (pages 5 to 8), the Appendix (pages 138 to 146), and Index (pages 149 to 157).

THE APPENDIX

The Appendix (pages 138 to 146) contains an alphabetical list of the popular names of insects and plants discussed, together with their scientific names, credit for their determination, and illustration and page references. The Appendix is mainly for the benefit of those wishing to study the subject more fully than has been done in this Bulletin.

THE INDEX

The Index will be found at the back of the book, on pages 149 to 157.

THREE METHODS FOR LOCATING DESIRED TEXT

1. If you know the name of the insect, use the Index (pages 149 to 157) or the Appendix (pages 138 to 146) to find the pages of the Bulletin on which it is discussed.

2. If you know the nature of the damage, but not the name of the insect doing it, use the "Key for Determining Insect Injury to Sugar Beets" (pages 5 to 8) or the Outline (page 3).

3. If you have one of the suspected insects, but do not know its name, use the Colored Plates (pages 11 to 27).

Use both Methods 2 and 3 when possible, to make identification more positive.

In case of doubt as to the identity of an insect or other specimen, or as to the nature of an injury, competent advice can always be obtained by consulting the authorities of the Agricultural College, the County Agents, or The Great Western Sugar Company's fieldmen.

REFERENCE FIGURES

The small elevated figures found occasionally throughout the text after the mention of some insect, refer to the corresponding marginal figure in the Appendix. The purpose of the reference is to connect the particular species to its scientific name.

BIBLIOGRAPHY

The Bibliography (pages 147 and 148) contains a list of publications on related subjects. Some of these have been drawn upon in the compilation of this Bulletin, and credit given in the text.

OUTLINE OF THE BULLETIN

INTRODUCTION

Outline of the Bulletin
Key for Determining Insect Injuring Sugar Beets
Colored Plates

CHAPTER I

Insects in General..... (a) Structure
(b) Development
(c) Classification
(d) Methods of Control

CHAPTER II

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(2) White Grubs
(3) Wireworms
(b) Sucking.....(1) Sugar Beet Root-louse
(2) Sugar Beet Nematode
(3) Root-knot Nematode or Gallworm

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Leaf Feeders.....(a) Biting.....(1) Caterpillars
(2) Beetles
(3) Grasshoppers
(4) Field Crickets
(5) Leaf-miners
(b) Sucking.....(1) Aphids or Plant-lice
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(3) Leaf-hoppers

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Beneficial Insects....(a) Predacious.....(1) Beetles
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EXPLANATION OF KEY FOR DETERMINING INSECT INJURY TO SUGAR BEETS

The method of using the Key (pages 5 to 8) is illustrated below by imagining a case of injury and following it through the Key until we come to the point where we get a clue to the insect causing the damage.

Example: In going through the field while the thinners are at work, we notice a beet here and there which is wilted and cut off just below the surface of the ground. Take your Key and begin at "A." This says that the leaves of the plant are wilted while those of the surrounding plants remain normal. This is true of the plants we found, so we read what comes under "1." As our beet is cut off below the surface of the ground "1" fits our case, so we continue to "a" and read: "Plants small. Damage occurring before or shortly after blocking and thinning". As the thinners are at work in our field this again fits our case, so we pass on to the single star (*). Here we read: "Plants cut off at or just below the surface of the ground," etc. This is our case exactly, and at the end we read: "Look for Cutworms." Thus the Key indicates that cutworms are at work on our beets and refers us to pages 38 to 48 of the Bulletin, where this insect is discussed.

Let us suppose that when we read the paragraph under the single star (*) we found that this did not describe our beet. We would then pass on to the double star (**), and if the beet we have has been injured by any of the insects discussed in this Bulletin this paragraph should describe the way it is injured.

If the injury was not indicated by a wilting of the leaves we pass from the capital "A" to capital "B", on page 6, and if this does not fit our case we pass on through the capital letters until we do find the description. When we find it we pass through the other steps which are indicated by figures, small letters, etc., until we come to the place where the insect causing the injury is named.

While this Key may not fit all cases exactly, yet it should enable one to determine quite closely what insect is causing the injury noticed. Then if the discussion of this insect and the nature of its injury are read and the insect, if one is secured, is compared with the pictures in the Colored Plates, there should be little difficulty encountered in identifying the culprit.

In case of doubt competent advice can always be obtained by consulting the authorities of the agricultural colleges, county agents or the sugar company's fieldmen.

KEY FOR DETERMINING INSECT INJURY TO SUGAR BEETS

A. Leaves of plant wilted while those of surrounding plants remain normal.

1. Plants cut off above the surface of the ground, at varying depths below, or with portions of the root surface eaten away, leaving shallow depressions or deep pits with darkened walls.

   a. Plants small. Damage occurring before or shortly after blocking and thinning.

      * Plants cut off at or just below the surface of the ground. Damage most apt to occur where beets follow alfalfa or grain, timothy or abandoned crops, and on fields adjacent to alfalfa.

        Look for Cutworms (pages 38-48).

      ** Plants cut off an inch or so below the surface of the ground. Tip of root as pulled from the ground dark, almost black. Damage most apt to occur where beets follow alfalfa, sod, pasture or meadow.

        Look for: White Grubs (pages 48-52);
        Wireworms (pages 52-54).

   b. Beets larger. Damage occurring from time roots attain the size of one's finger until harvest.

      * Plants always cut off above surface of ground or with deep cavities pecked into the crowns. Damage most apt to occur near standing alfalfa or waste land overgrown with weeds or other tall growth.

        Damage caused by Pheasants.

      ** Plants never cut off above the surface of the ground.

        ° Portions of root surface eaten away, leaving shallow depressions with rough darkened surface. Root often entirely eaten off several inches below the surface of the ground. Damage usually occurring where beets follow sod, pasture or meadow, or on river bottom land.

          Look for White Grubs (pages 48-52).

        °° Portions of root surface eaten away, leaving small, deep, dark-walled pits. Roots of large beets never entirely eaten off. Damage most apt to occur where beets follow alfalfa, sod, pasture or meadow.

          Look for Wireworms (pages 52-54).

2. Plants not cut off. Portions of root surface not eaten away. Leaves often dull, dark green, as though plants were suffering from lack of moisture; or leaves yellowish green.

a. Only young heart leaves wilted. Wilting usually most apparent at tip of leaves. Later these tips become dry and brown.

Look for Tarnished Plant-bugs (pages 122-123).

b. Entire plant more or less wilted.

* Root either covered with whitish substance or with abnormal development of fine roots or wart-like swellings.

° Root more or less covered with a white mould-like substance. Many whitish-yellow lice mixed with this substance. Lice present in nearly every field regardless of previous crop. Damage more apt to be severe in dry years than wet.

Sugar Beet Root-lice (pages 55-59).

°° Root with abnormal development of fine rootlets. Many small pearly-white bodies clinging to these rootlets. (See Figure 9, Plate III, Page 15 and Figure 6, Page 60). In late fall many of these bodies become rich brown in color. Injury most apt to occur on old beet ground.

Sugar Beet Nematode (pages 59-64).

°°° Roots with wart-like swellings. Rootlets with small, almost round swellings resembling beads on a string. (See Figure 8, Page 64). Injury most apt to occur on old beet ground.

Root-knot Nematode or Gallworm (pages 64-66).

** Root normal. Not as above.

° Damage usually most severe in fields near poor stands of alfalfa overrun by shepherd's-purse, fanweed and other weeds of the mustard family. Fields adjacent to waste land overgrown with these weeds very apt to be damaged, also, as weeds begin to ripen.

Look for False Chinch Bugs (pages 119-121).

B. Leaves dull green, light yellow, or blotched with whitish green or purple.

1. Leaves dull green, as though plants were suffering from lack of moisture. In severe cases leaves become light yellowish green. Plants making poor growth.

Look for: Sugar Beet Root-lice (pages 55-59);
Nematodes (pages 59-66).

2. Leaves blotched with whitish green. Not abnormally curled.

   Look for: Plant-lice (pages 111-116); Leaf-hoppers (pages 123-128).

3. Leaves blotched with purple (Figure 1, Plate VIII, Page 25).

   Look for Leaf-hoppers (pages 123-128).

C. Leaves with portions of blade or stem eaten away. Sometimes crowns of beets eaten also.

1. Leaves eaten full of small holes (Figure 1, Plate IV, Page 17). Injury most apt to occur during spring and early summer.

   Look for Flea-beetles (pages 91-93).

2. Leaves more or less completely eaten, or portions eaten from margins (Figure 11, Plate III, Page 15).

   a. Leaves often more or less covered with a fine whitish web. Damage caused by worms about one inch long when fully grown. Worms very active, throwing themselves from the plant when disturbed. Often hanging from leaf by a single thread of web, especially when young.

      * Worm dark green, striped, several dark circular spots on each segment of the body (Figure 6, Plate V, Page 19). Web when present usually on blade of leaf near its base. Heart leaves usually eaten last. Excrement of worms scattered over leaves in form of small dark pellets.

        Sugar Beet Webworms (pages 67-78).

      ** Worm lighter than webworm. A pink or flesh-colored stripe on each side (Figure 1, Plate VI, Page 21). Web often among heart leaves. A long tube leading from web to clods on the surface of the ground. Worm usually concealed at end of this tube when not feeding.

        Alfalfa Webworms (pages 84-85).

   b. Leaves not webbed.

      * Damage occurring during spring and early summer, while beets are still small.

        ° Damage usually most severe on wet alkali land or near such land.

          Look for Alkali-beetles (pages 89-90).

        °° Damage not associated with alkali land. Usually most severe near alfalfa, ditch banks, fence rows or waste land. Edges of leaves eaten. In severe cases entire plant destroyed.

          Look for Spinach Carrion-beetles (pages 94-95).

** Damage usually occurring during midsummer or later.

° Damage most severe on wet alkali land or near such land. Tender portion of leaf eaten, only a network of veins remaining, which soon become dry and brown.

Look for Alkali-beetles (pages 89-90).

°° Damage usually most severe at borders of field near wild land, waste land, ditch banks and fence rows where grasshoppers are numerous, or near alflafa or waste land overrun with sweet clover, or near grain fields.

Look for: Grasshoppers (pages 98-109);
Alfalfa Loopers (pages 81-84);
Western Army Cutworms (pages 41-45).

°°° Damage usually slight, only a beet leaf here and there being eaten. Not confined to border, but occurring throughout entire field.

Look for: Yellow-bear Caterpillars (pages 86-87);
Zebra Caterpillars (pages 87-88);
Variegated Cutworms (pages 47-48).

D. Leaves very much curled and distorted. Veins much enlarged, often bearing cone-shaped points (Figure 5, Plate VIII, Page 25).. Root small and stunted. Rootlets abnormally developed (Figure 7, Page 60). Crown often covered with a sticky syrup-like substance. Curly-top (pages 124-125).

Look for Sugar Beet Leaf-hoppers (Pages 123-126).

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Note: In case of enlargement, a natural size black and white outline drawing is shown beside the colored picture. Exceptions to this plan on Plate I are Figures 7 and 14.

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C M PRESTON

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Note: In case of enlargement, a natural size black and white outline drawing is shown beside the colored picture. Exceptions to this plan on Plate II are Figures 2, 8, 11, 12, 13 and 17.

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Note: In case of enlargement, a natural size black and white outline drawing is shown beside the colored picture. Exceptions to this plan on Plate III are Figures 2, 8, 9 and 10.

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Fig. 1
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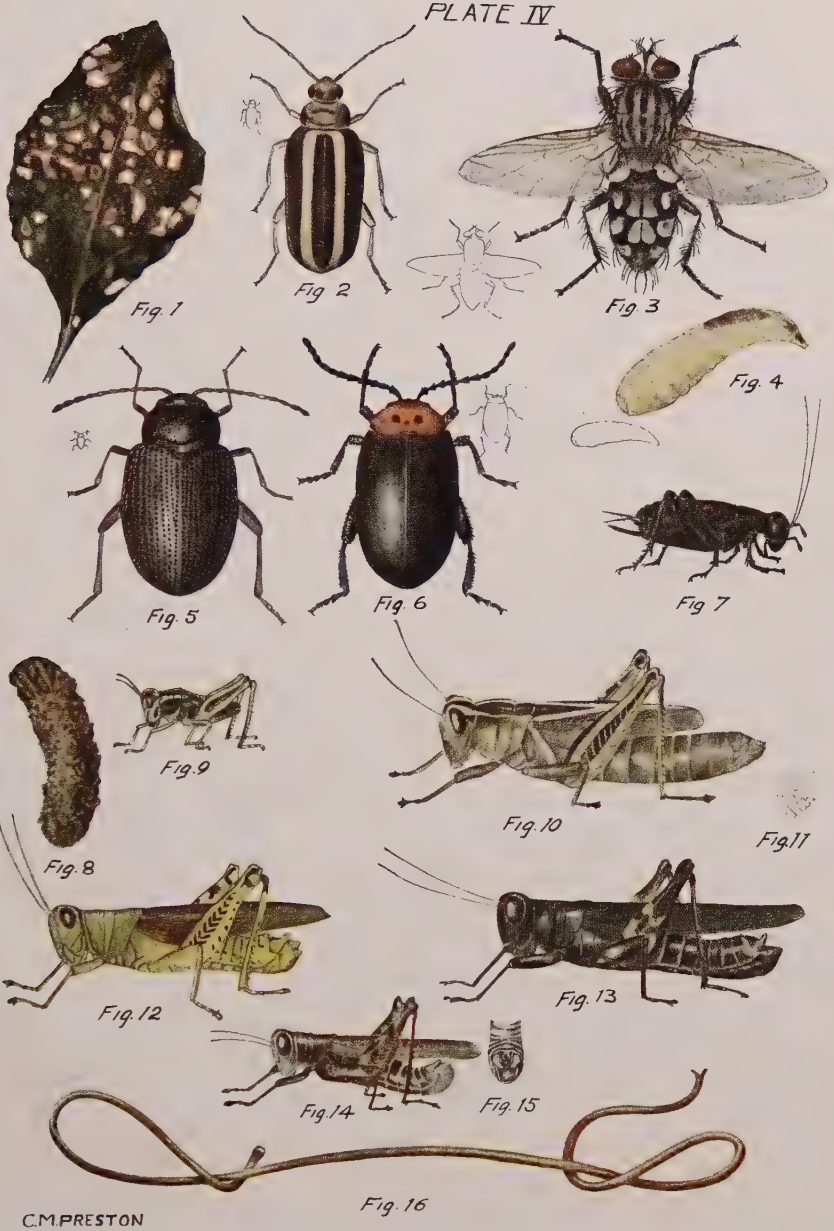
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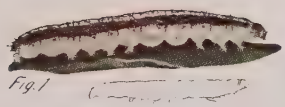

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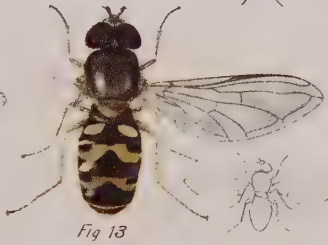

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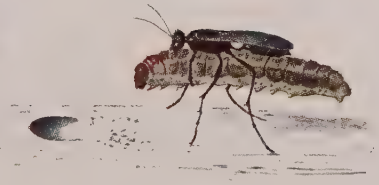

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Note: In case of enlargement, a natural size black and white outline drawing is shown beside the colored picture.

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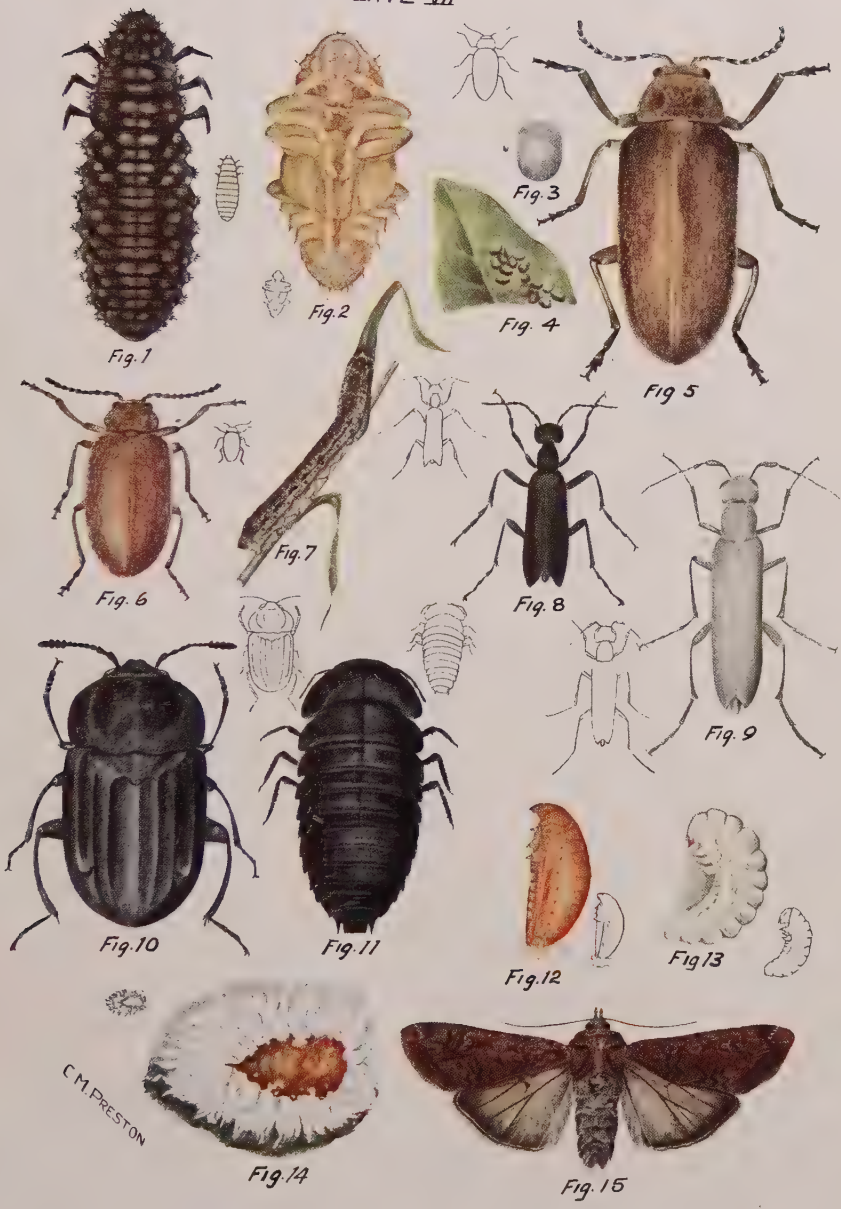
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Note: In case of enlargement, a natural size black and white outline drawing is shown beside the colored picture. The only exception to this on Plate VIII is Figure 2.

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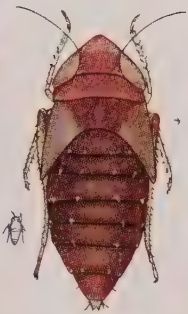

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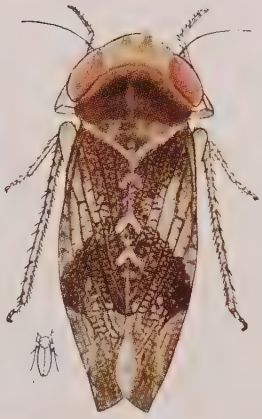

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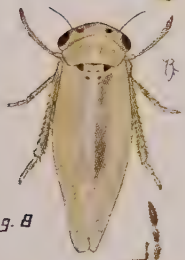

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Note: In case of enlargement, a natural size black and white outline drawing is shown beside the colored picture. Exceptions on Plate IX are Figures 9, 11, and 22.

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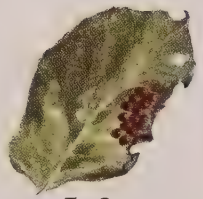

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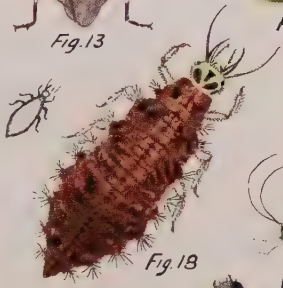

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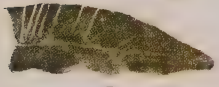

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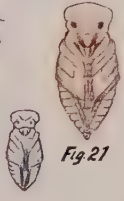

Fig. 21

Fig. 22

Fig. 23

Fig. 24

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CHAPTER I

INSECTS IN GENERAL

Knowledge of the structure, development, classification and methods of control of insects in general will enable the reader to understand better the text dealing with any individual insect. The purpose of the brief discussion in this chapter is to give that preliminary setting.

STRUCTURE

All adult insects have the head, thorax (chest) and abdomen more or less distinctly separated. Attached to the front of the head are two antennae, or feelers, as they are popularly called. The mouth parts are formed for biting or sucking. Those of biting insects, such as grasshoppers, flea-beetles and alkali-beetles, consist of hard, sharp-edged jaws. Sucking insects, such as the false chinch bug, plant-lice and others, have the mouth parts prolonged into a long, straight beak which is often jointed. In the case of moths and butterflies the larvae have biting mouth parts while those of the adults are in the form of a slender proboscis, which is carried coiled beneath the head. In the adult stage there are always three pairs of legs attached to the thorax. These three pairs of legs are present in the immature stages of beetles, the true bugs, moths and butterflies, while the young of the two-winged flies, bees, wasps and others are legless. Aside from the true legs, which are located near the head, caterpillars have from two to twelve fleshy leglike organs on the abdomen. These are called prolegs or props. These prolegs are furnished with both hooks and suction pads. Most adult insects have one or two pairs of wings, which are also attached to the chest.

Insects breathe through small openings or spiracles in the abdomen. From these openings the air is carried through tubes called tracheae, leading to the various parts of the body.

Spiders, ticks and mites are not insects, but belong to a group of invertebrate animals which have the head, thorax and abdomen closely united and possess four pairs of legs in the adult stage; however, in the immature stages some have but three pairs.

DEVELOPMENT

In the course of their development most insects undergo remarkable changes in form. These changes constitute what is known as insect metamorphosis.

One order of insects develops without change in form or without metamorphosis. The young when hatched from the egg have the same form as the adult. A common representative of this group is often seen floating in dense masses on water. Another is sometimes seen hopping about on the snow during warm days in early spring in northern latitudes.

The insects belonging to another class undergo considerable change in form during their development, but the young resemble the adults

quite closely; therefore the metamorphosis is said to be incomplete. Grasshoppers, plant-lice and the true bugs are common examples of this class. The young of these insects are called nymphs.

The early forms of many insects, like the butterflies, moths, flies, bees and beetles, differ so from the adults that there is no resemblance whatever between the two. These insects pass through at least four stages, the egg, larva, pupa and adult, each differing in form from the other. For this reason their metamorphosis is said to be complete.

The Egg

The egg is the first stage in the development of any insect. The eggs of some insects, like the plant-lice, remain in the abdomen of the mother until the young are fully developed and hatched. Insect eggs vary greatly in form, as can be seen by referring to the figures given in the Colored Plates.

The Larva

The larva is the form of an insect immediately following the egg. It is then in the stage of growth, and many of our common insects damage crops more severely during this period of their lives than at any other time. Larvae differ greatly in form in the different orders. The larvae of moths and butterflies are called caterpillars; those of flies are called maggots; those of some beetles are called grubs and others worms. Caterpillars are often called worms also. The legless larvae of bees, wasps and related insects are sometimes called grubs.

The Pupa

The pupa is the third or resting stage. The larva becomes a pupa when it has completed its growth. In this stage the insect has very little or no power of movement, being unable to do more than wriggle the tip of the abdomen at most. The pupa of a butterfly or moth is called a chrysalis; the hardened larval skin within which the pupa of some two-winged flies is formed is termed a puparium.

The Adult

The adult is the fourth and final stage in an insect's development. No further growth takes place after this stage is reached. Only enough food is taken by the adult to sustain life; in fact some adults do not feed at all, their mouth parts having been lost through disuse. The principle function of the adult is that of reproduction.

The Integument

The skin or integument of an insect is composed of a tough, horny substance called chitin (pronounced ki-tin). At certain periods during the larval stage this becomes so hard that it cannot stretch and soon becomes too small for the growing insect. In the meantime a new skin is forming underneath the old one, which splits open. The insect then frees itself from its old coat. This process is called molting. The new skin is at first soft and stretches to accommodate the increasing size of the insect. Soon, however, it becomes hardened and must in turn be cast off. Thus, in the course of their development insects shed their skins several times. After reaching the adult stage molting ceases and all growth stops.

CLASSIFICATION

The insects that injure agricultural crops can be roughly grouped into two classes: those that feed upon the roots and underground parts of plants, or "root feeders;" and those that feed upon the leaves and other parts of plants above the ground, or "leaf feeders."

Each of these groups can in turn be divided into two other classes: insects which bite their food, or "biting insects," and those which suck their food, or "sucking insects."

Both classifications are most important from the viewpoint of insect control.

The mouth parts of the biting insects consist of an upper and lower lip between which are two pairs of jaws with which portions of the food plant are bitten out and masticated. Attached to these jaws are slender, jointed organs used in guiding the food to the mouth or as sense organs.

The mouth parts of sucking insects are modified into a long, jointed tube or beak and several hair-like bristles which are enclosed within it. In feeding, the beak is placed against the surface of the plant while the bristles or piercing organs are forced into the tissue. The plant juice is then sucked up through them by a pumping motion of the mouth.

METHODS OF CONTROL

There are two general methods of insect control, the cultural or natural method, and the artificial method.

The natural method consists of handling the soil or the crop in such a way as to prevent or reduce insect injury, and in fighting injurious insects with their natural enemies.

The artificial method consists of the application of any substance to a crop for the purpose of killing attacking insects or making the plants so distasteful to them that they will not feed upon them.

Natural Methods of Control

Application of the natural methods of control depends largely upon the habits and life history of the insect to be controlled. For example, in the case of the grasshopper we know that its egg stage is passed in the ground during the fall and winter. Fall plowing, harrowing and discing will kill the grasshopper in the egg stage.

Crop Rotation

Crop rotation is one of the principal factors in insect control. Many insects feed upon only one crop or those closely related botanically. It is evident, therefore, that if the same crop is planted on a field for several years in succession the insects attacking it are likely to accumulate in and about it until serious damage results. The length of rotation necessary to insure against injury by an insect or other crop pest, depends upon the pest in question. For example, the corn root worm can be controlled by alternating corn with any other crop; while white grubs and wireworms require a three or four year rotation; and the sugar beet nematode a much longer rotation.

Other insects deposit their eggs upon certain crops or in the soil where these crops are growing or have grown. Loss can be avoided by following such crops with others which are not attacked by this class of insect.

Plowing

Many insects pass certain tender stages of their development in the ground or on plants in the fields. Plowing infested fields at the proper time will do much toward destroying such insects.

Late Planting

Injury can sometimes be prevented by timing the planting of crops so that they will not come up until danger of infestation is passed.

Burning

Many insects spend the winter in hibernation beneath the trash or crop refuse on and about fields. If this waste matter, dead weeds and grass about fence rows and ditch banks is burned during the fall or winter, many insects will be destroyed which would otherwise damage crops the following spring.

Clean Culture

Nearly all injurious insects fed upon wild plants before the land was broken up and planted to crops. If weeds are allowed to grow in a crop or about the fields, ditch banks, fences or roadsides, they attract these insects to the vicinity. After the wild food plants have been destroyed, the insects turn their attention to crops and much damage results. Clean cultivation is always profitable from the standpoint of insect control as well as for other reasons.

Artificial Method of Control—Insecticides

What substance to use and how to use it in artificial control depends upon whether the insects are **biting** or **sucking** insects. There are two general classes of insecticides, those which kill after they are eaten (stomach poisons), and those which kill by coming in contact with the insects (contact poisons). The first is used against insects which bite their food, and the second against those which suck it.

Control of Biting Insects

In the control of most biting insects poisonous substances such as Paris green and arsenate of lead are used. These are applied either as a spray mixed with water or dry. In the latter case the poison is mixed with low grade flour, air slaked lime or some other fine powder and dusted onto the crop. The poisons are often mixed with some substance which the insects will eat, and this poisoned bait, as it is called, is scattered over infested fields.

In the control of some biting insects it is necessary to kill them while in the egg stage. This is done by spraying with oils which can be mixed with water or with lime-sulphur wash (See page 115). These oils are petroleum products rendered soluble by the addition of vegetable oils and are known by the trade name of "miscible oils."

Many biting insects devour the entire leaf in feeding, while others feed on the under side of the leaves only, eating all but the upper surface. In applying stomach poisons it is very essential that the location of the insects while feeding be known. If they feed on the under side of the leaves the sprayer must be adjusted so that the poison is applied to the lower surface.

Sometimes arsenical poisons burn the leaves of plants, especially if the application is heavy. This is due to free arsenious acid in the material used. The addition of a little quick lime to the water in which the poison is mixed will prevent this burning. When lime has been added the solution must be carefully strained to remove particles of lime which would otherwise clog the nozzles.

Control of Sucking Insects—Contact Poisons

In the control of sucking insects the contact poisons kill the insects either by corroding their bodies or by clogging their spiracles, thus causing strangulation. Black-leaf 40 (See page 114), kerosene emulsion (See page 114), the so-called insect powders and soluble oils are standard remedies for sucking insects. As the name implies, these substances must come in actual contact with the insect to kill it.

Repellents

A repellent is any substance the presence of which on plants makes them so distasteful to insects that they will not feed upon them. Mixtures containing tobacco preparations or soap, especially whale oil soap, are effective as repellents.

SPRAYERS

A. TRACTION SPRAYER

For field use any one of the many makes of traction sprayers (Fig. I, Page 33) is recommended.

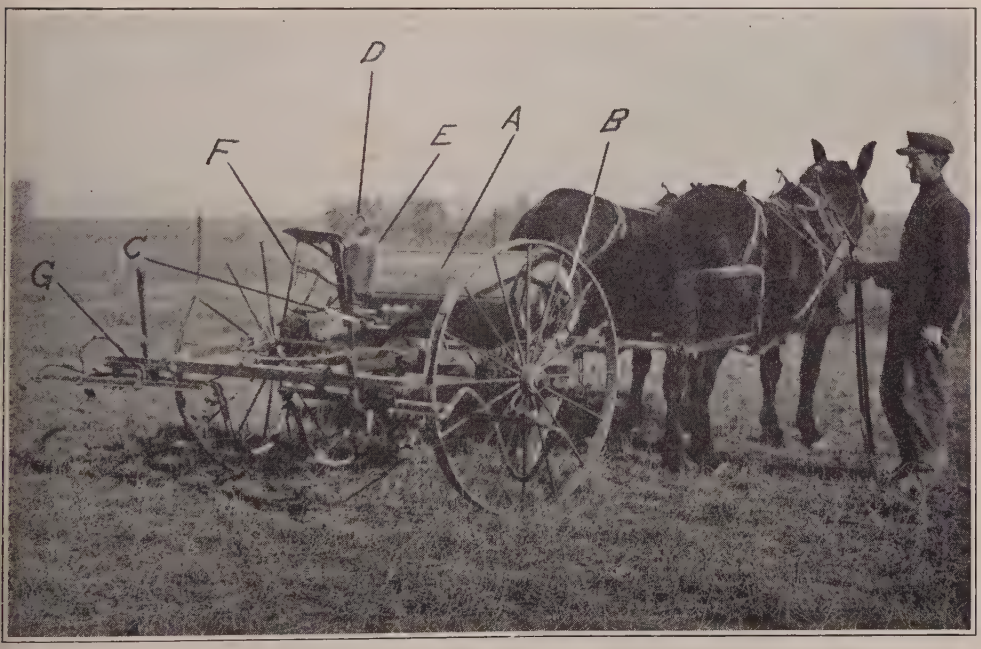

Fig. 1. A Good Type of Traction Sprayer for Field Use

Such a machine should embody the following features:

A. A tank of sufficient capacity to permit of spraying large fields without having to fill it in the center of the field. A tank holding 50 gallons is large enough for practical purposes.

B. A revolving agitator within the tank to keep the poison in suspension.

C. A force pump to maintain a pressure at the nozzles in order to produce a fine mist-like spray. This pump should be driven by the wheels of the sprayer.

D. A pressure gauge.

E. A large air chamber.

F. An adjustable safety valve to prevent bursting the rubber hose connections.

G. An adjustment whereby the machine can be adapted to variable distances between rows without changing piping, hose connections or nozzles.

A means of adjusting the wheels to varying widths of rows.

CARE OF SPRAYER

Remove Rust Scales

There are certain soluble acids in Paris green which act upon the iron parts of the sprayers, especially the iron piping. This action produces large quantities of rust which falls away from the pipe in scales. These scales will clog the nozzles unless the piping and other metal parts are thoroughly cleaned.

Remove Dry Paris Green

There is always some Paris green left in the piping, tank and nozzles. This is apt to cause the same trouble when you start the sprayer as the rust scale mentioned. The barrel, or whatever kind of tank there is on your machine, should be thoroughly cleaned.

Repair Hose Connections

Be sure that all hose connections are in good repair.

Clean Nozzles

Often times the nozzles become clogged with dry Paris green. Therefore all nozzles should be taken apart and thoroughly cleaned.

Examine Pump

The pump is one of the most important parts of a sprayer. Too much pains cannot be taken in seeing that the pump is in perfect condition. Remember that the pump will not work properly if not properly packed.

Examine Valves

Next to the packing, the valves are most important. A steady pressure cannot be maintained if the valves are not in perfect condition.

Clean Relief Valve

The relief valve which regulates the pressure should be examined, since, if this fails to work, the hose connections are very apt to be blown off.

Neckyoke and Eveners

Most beets are planted 18 or 20 inches apart or 16 and 24 inches. In either case three rows of beets should be between the wheels and the wheels 60 inches apart. The eveners and neckyoke should be 60 inches long, so that the horses walk in front of the wheels. Less damage will be done to the crop from broken leaves and crushed crowns if your machine is equipped in this way.

Setting the Nozzles

The nozzles should be so placed as to make it possible to spray thoroughly all surface between the end nozzles. There are so many styles of nozzle equipments and frames that it would require too much space to explain in detail the setting of all. Let it be sufficient to say that four single nozzles should not cover more than 5 rows of beets and 6 single nozzles 7 rows. If the double nozzles are used, 4 pairs will cover 8 rows and 6 pairs 12 rows. In spraying very small beets the nozzles should be placed directly over the rows.

Testing the Pump

Before attempting to do any spraying, test the spray pump thoroughly. The pressure regulates the kind of spray your machine throws (fine or coarse), also the amount of water applied to an acre of ground. **Eighty pounds pressure produces the fine mist-like spray required for best results.**

Test Your Sprayer

It is the poison applied to an acre of beets and not the water which kills the worms. Quick and satisfactory results are secured by the use of 4 pounds of Paris green per acre. Unless you know how much water your sprayer applies to an acre, you cannot know how much poison to use in a tank of water. For example, if a sprayer equipped with 4 double nozzles and producing a pressure of 80 pounds will cover an acre with 50 gallons of water, you should mix 4 pounds of Paris green with 50 gallons of water. If the pressure falls very much below 80 pounds, less water will be applied to an acre and more Paris green will have to be added to a 50-gallon tank of water.

To test your sprayer fill the tank with water, put the pump in gear, then drive along the road and measure the distance traveled in discharging all of the water through the nozzles. Multiply this distance, measured in feet, by the width of the number of beet rows you spray; say 5 twenty-inch rows or 8.3 feet, and divide this by 43,560, which is the number of square feet in an acre. This will give you the part of an acre you spray with one tank of water. Many failures in spraying are due to using too little poison, and much loss in money results from using too much. Avoid this by testing your machine. From the above you can determine the amount of Paris green to use with a tank of water to apply the 4 pounds per acre.

KNAPSACK SPRAYER

Fig. 2. Knapsack Sprayer

For use in gardens or for spraying berry bushes and ornamental shrubs, the knapsack sprayer (Fig. 2, Page 36) is very convenient. This sprayer can be placed on the ground or carried as shown in the figure. Where the garden or the number of plants to be sprayed is small this sprayer is not so well adapted to the work as the hand sprayer.

HAND SPRAYER

The hand sprayer (Fig. 3, Page 36) is suitable for spraying house plants, or a very small fruit or vegetable garden. It can also be used to apply repellents to live stock. Where one has only occasional use for a sprayer to spray a few plants this type is recommended because of its small cost.

Fig. 3. Hand Sprayer

The accompanying picture (Fig. 3-a) illustrates a home-made sprayer, costing approximately $25.00. This machine was successfully used during the 1919 growing season in the Fort Collins, Colorado district. Any hand-power spray pump may be used.

A HOME-MADE SPRAYER

Fig. 3-a. A Home-made Sprayer

CAUTION

Since Paris green is a poison, due care should be exercised in handling it.

Be careful not to get Paris green on the hands, face, or other parts of the body, or to rub the face or body with the hands if any of the green should get on them. The safest plan is to wear gloves.

The poison is absorbed into the pores of the skin and causes a severe rash or breaking out. This absorption is more rapid when one is perspiring.

Inhaling the dry poison may cause local poisoning of the nasal passages.

Long continued handling of Paris green with bare hands may result in systemic poisoning which is accompanied by typical internal arsenical poisoning symptoms.

The average person will become poisoned locally only after long and continuous contact with Paris green, but some individuals are much more susceptible than others. This susceptibility cannot be determined beforehand, hence the increased need for caution.

In measuring Paris green use a long handled dipper.

Always use a wooden paddle for mixing it.

Destroy all cans or paper containers in which Paris green is received, after emptying them. Children may be poisoned by playing with them.

CHAPTER II

ROOT FEEDERS

Taken as a class, those insects which inhabit the soil and feed upon the roots and other underground parts of plants are among the worst enemies of field, orchard and garden crops.

Living and feeding, as they do, below the surface of the ground the greater part of their lives, the root feeders are seldom observed at work in the field.

The effect of injury by root feeders upon the leaves and other visible parts of plants is often attributed to many causes but the right one, and its association with the insect is often not suspected until much damage has been done, if at all.

Their subterranean habits, together with the rapidity with which some forms multiply, and the ease with which others are disseminated over large areas, make them, with few exceptions, extremely difficult to control.

Furthermore, the study of the habits, life history and control of many root feeders is attended by peculiar difficulties, because of which our knowledge of them is often so meager that we are unable to apply effective means of control when some insect of this class suddenly appears in damaging numbers in our fields.

Probably the best known and most destructive root feeders are the cutworms, white grubs, wireworms, corn root-worms, the corn root-louse and the sugar beet root-louse. To this may be added the sugar beet nematode and other closely related eelworms.

A. BITING ROOT FEEDERS

(Cutworms, White Grubs, Wireworms)

1. CUTWORMS

The name "cutworm" is applied in a general way to all of the hairless larvae (caterpillars) of a group of moths or millers called "owlet moths," from the fact that they fly mostly at night and have eyes that shine in the dark.

Probably no other insects are more dreaded in those sections where they cause large annual crop losses, than are the various cutworms. Like the evil gnomes of old, who sallied forth on moonless nights to wreak vengeance upon some hapless wayfarer, the cutworms come forth from hiding, and, under cover of darkness, despoil the farmers' crops; or, like the "sappers" of an invading army, these invaders of our fields tunnel from plant to plant, leaving a trail of death and destruction in their wake.

NATURE OF INJURY

If, in walking through a beet field, dead and wilted plants are seen; if stools of grain in grain fields are dying or the stand is becoming thin; or

if alfalfa starts very slowly or makes an indifferent growth in the spring, the fields should be examined for cutworms.

If cutworms are causing the injury the dead and wilted beets or dying stools of grain will be found cut off at the surface of the ground, or just below it. Should these plants still be attached to their roots, there being no evidence of their having been partially gnawed off, cutworms are not responsible for the plants dying. In case the plants have been killed for some time the dead and dried leaves may have been blown away, leaving the ground bare. In this case the stubs of the plants will be found if the soil is removed to a depth of one-half inch or so.

When the slowness in starting or indifferent growth of alfalfa is due to cutworms many new shoots will be found wilted and dead. These will be gnawed off near the crown of the plant. As in the case of beets and grain, shoots that are not at least partially gnawed off have not been killed by cutworms.

While the foregoing is usually sufficient evidence that cutworms are or have been injuring a crop, yet the real proof is in finding the worms.

WHERE TO LOOK FOR THE WORMS

Most cutworms, like the moths which produce them, are nocturnal in habit. They lie hidden beneath trash or just below the surface of the soil during the day, coming forth toward dusk and during the night to feed. When very numerous and during cloudy, damp days, they sometimes move about quite freely in the early part of the day.

In infested fields the worms will usually be found buried in the soil near some plant which has been recently cut off. In alfalfa they will be found buried near the crowns of the plants or under the trash scattered over the field. Many times they accumulate under boards and other objects lying on the surface of the ground. Careful watch should be kept for worms before planting as damage can best be avoided by destroying them before the crop is sown.

METHODS OF CONTROL

Poisoned Bait; Kansas Mixture

The best known method of killing cutworms is the use of poisoned bait. A poisoned bran mash known as **Kansas Mixture** seems to give the best results. The formula for use against cutworms is as follows:

20 lbs. bran or shorts;
1 lb. Paris green;
2 qts. molasses (any cheap grade or beet molasses);
2 lemons or oranges (lemons preferred);
3 gals. water.

How to Make Kansas Mixture

Thoroughly mix the bran or shorts and the Paris green dry. Chop the lemons or oranges, rind included, very fine. If a food chopper is available, use this. Add the molasses and chopped fruit to about one-half of the water and stir until the molasses is dissolved. Add this mixture to the bran and Paris green and mix evenly. The rest of the water should then be added a little at a time, stirring the mixture while doing so, and until the whole mass is evenly moistened. When this

has been done the bran should be just moist enough to stick together, but not so wet that it will not crumble freely. In this condition it can be evenly and thinly scattered over the field to be treated.

How to Apply the Bait

The poisoned bait should be scattered broadcast over the infested field. This can be done by hand, care being taken to prevent large lumps from being left in the field unbroken. If the bait is thinly and evenly scattered there is no danger of poultry or livestock being poisoned by eating it. If properly scattered a mixture made of 20 pounds of bran will cover 2½ acres.

Time to Put Out the Bait

Since the cutworms, as a rule, do not begin feeding until late afternoon or early evening, the bait should not be spread until about sundown. If spread earlier in the day, especially if the weather is hot and dry, the bait will become dried out before the worms begin feeding. In this case the results are apt to be disappointing. It is claimed that cutworms feed much more freely on shorts when dried out than on bran.*

Treating Fields Before Planting

Infested fields should be treated with poisoned bait **before** planting. If properly applied one application of Kansas Mixture is sufficient to rid a field of cutworms. After being treated in this manner a field can be planted with safety.

Other Poisoned Bait

Freshly cut clover or alfalfa thoroughly sprayed with Paris green and water (1 lb. Paris green to 25 gallons water) and spread over infested fields is often substituted for Kansas Mixture. It is very doubtful if this is as satisfactory as the poisoned bran mixture. This method should be avoided because of the danger of poisoning live stock.

Rolling

Rolling is sometimes recommended for killing cutworms. However, it is a doubtful method and one which is very apt to be disappointing in its results. Unless the surface of the field is very smooth and compact, rolling is a waste of time for this purpose. If done at all it must be done at night when the worms are moving on the surface. Generally speaking, rolling is not to be recommended.

Discing

Discing is even less effective than the roller, for destroying cutworms, and is not recommended.

Plowing

Deep fall plowing will often give good results, especially if the soil is thoroughly disced before plowing and the surface well worked down afterward.

Replowing of infested fields in the spring, if the plowing is deep and the surface thoroughly worked afterward, has given good results when the season is not too far advanced for the planting of early maturing crops.

*E. H. Streckland, "Control of Cutworms in the Prairie Provinces," Circular No. 6, Department of Agriculture, Dominion of Canada (1916).

Late Planting

Late planting may sometimes be resorted to as a means of preventing loss by cutworms. However, before resorting to this means the best plan, if one is in doubt as to the identity of the particular cutworm in question, is to send some of the worms to the State Entomologist, to the Experimental Department of The Great Western Sugar Company, Longmont, Colorado, or to some one else familiar with these insects and qualified to give advice regarding them. If this is done much time and many dollars may be saved. Before resorting to late planting read carefully what follows about the different species of cutworm, especially the Pale Western Cutworm.

(a) WESTERN ARMY CUTWORM

(Figs. 1, 2, 3 and 4, Plate I, Page 11)

The name "western army cutworm" has been applied to this species because under favorable conditions it becomes very numerous and at such times travels en masse in much the same way as the true army worms.

It is also often called the "alfalfa cutworm," because of its preference for this crop. In Northern Colorado it seldom injures crops unless they are planted on recently broken alfalfa land or in fields adjoining infested alfalfa fields.

DESCRIPTION

The Worm

Figure 1, Plate I, Page 11 represents a full grown western army cutworm, natural size. This worm is marked with various shades of brown above, while the lower part is a dirty white. There are usually several dark spots on each segment of the body. Each of these bears a short, stiff bristle. These bristles are not always easily seen with the naked eye. Some individuals are much darker than in the figure, while others are lighter. This is the most common cutworm in alfalfa fields.

The Pupa

Shortly after the cutworm becomes full grown it burrows into the soil to a depth of about two inches. The next few days are spent in wriggling and twisting about, making a cosy cell in the soil.

Rapid changes now begin to take place in the worm. It gradually shortens and changes from its original color to a dirty, whitish yellow. The skin, which has become much shrunken and wrinkled, now cracks open, exposing a yellowish brown object within. A few more twists and turns and the pupa (Fig. 2, Plate I, Page 11) frees itself from the skin which covered the worm.

The Moth

The change from worm to pupa is only the beginning. During the next two or three weeks nature is at work within the brown walls of the pupa forming a body, legs and wings and hundreds of feather-like scales (Fig. 4, Page 42) to cover them. When all is complete, our ugly cutworm has taken on still another form. The brown walls of the pupa burst open and after much pulling and straining the moth emerges. At each side of its body hang two crumpled objects. As we watch these they begin to expand and lengthen. In a very short time they have

developed into delicately colored wings. The cutworm has now reached the fourth or perfect stage, the moth.

These moths (Fig. 3, Plate I, Page 11) are easily recognized by the light stripe on the forward edge of the fore wing. A few individuals lack this stripe, the fore wing being colored as shown in Figure 4, Plate I, Page 11.

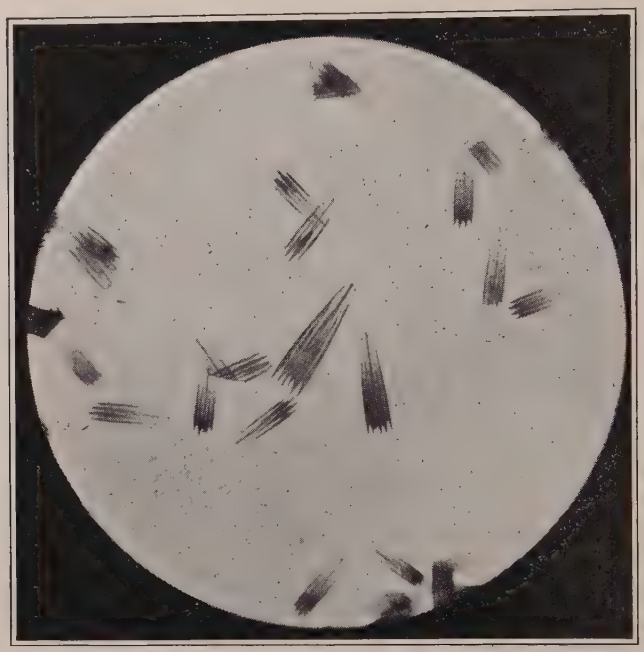

Fig. 4. Scales from Wing of Moth of Western Army Cutworm, highly magnified

LIFE HISTORY

Our knowledge of the life history of the western army cutworm is incomplete. However, recent investigations conducted by Prof. R. A. Cooley, Entomologist of the Montana Experiment station,* have determined some of the more important points.

Prof. Cooley and his associates draw the conclusion that the western army cutworm is single brooded in Montana. This is probably true of Northern Colorado as well.

The eggs are deposited, so far as is known, on bare ground, on clods of earth, stubble and dead roots on the surface of the soil. Each female moth is capable of laying several hundred whitish, ribbed, and more or less globular eggs similar to those which are shown much enlarged on Plate I, Page 11, Figures 11 and 12. The greater part of the egg laying is done during September and October.

The eggs hatch in about ten days under ordinary conditions, but a longer time is required if the weather is cool or the season advanced

*"Observations of the Life History of the Army Cutworm," Journal of Agricultural Research, Vol. VI, No. 23 (1916).

when they are laid. The young worms feed during the fall until winter comes on. As a rule little or no damage is noticed as a result of this fall feeding. With the coming of cold weather the worms become dormant, in which condition they remain until the coming of warm weather in the spring, when they resume feeding.

In seasons of normal temperatures the worms feed until about April 15th or May 1st. If the season is cold and backward the feeding period is prolonged. Under such conditions the worms have been known to feed until well into May.

Advantage can be taken of our knowledge of the feeding habits of this worm in the sowing of our crops. In case we have an infested field it can safely be planted to an early maturing crop by waiting until the worms have ceased feeding, which is normally about the middle of April in the latitude of Denver. Farther north, planting should be delayed until about May 1st to 10th.

The moths begin to appear in numbers about June 15th. From this time until the fore part of July they are most abundant. They often become a nuisance in dwellings, causing much annoyance by flying about the lamps. When very numerous the moths will be found under any object which affords concealment during the day. Old garments hanging on the sides of out-buildings seem to be favorite hiding places. The moths live until fall, when egg laying begins.

NATURAL ENEMIES

There are a number of parasitic and predacious insects which prey upon the western army cutworm. The most important of these are: Ichneumon-flies, Braconids, Chalcis-flies and ground beetles and certain species of digger-wasps. Several species of birds destroy great numbers of cutworms also.

Ichneumon-flies, Braconids and Chalcis-flies sting their eggs into the cutworms, using for this purpose a long slender organ called an ovipositor. This ovipositor is located at or near the tip of the abdomen. After the eggs have been placed in the body of the cutworm the little grubs hatch and immediately begin feeding. These grubs subsist upon the body fluids and fatty substances of the cutworm but do not destroy its vital organs until they are fully grown.

Ichneumon-fly

The larva of the Ichneumon-fly [10] (Fig. 5, Plate I, Page 11) does not kill the worm, which changes into a pupa before the parasite's work is finished. The moth never develops in a parasitized pupa, however, for the pupa is killed by the parasite, which gnaws its way out when it is fully developed. Instead of a moth coming forth to lay more eggs to infest our fields, the wasp-like Ichneumon-fly emerges, and if a female it deposits its eggs in other cutworms, thus carrying on the good work of ridding our fields of these pests.

Braconid

The larvae of the Braconid [2] (Fig. 6, Plate I, Page 11) kill the worm before it changes to a pupa. When fully grown the grubs gnaw their way out of the worm and proceed to spin about themselves little silken

([10–2]) See explanation of "Reference Figures," page 2.

cocoons (Fig. 7, Plate I, Page 11) in which their development is completed. These cocoons are sometimes fastened to the dead worm, sometimes to grasses or other plants, where they cling in clusters.

Chalcis-fly

The little Chalcis-fly [4] (Fig. 8, Plate I, Page 11) is one of the most interesting parasites which attack the cutworms. The parasitized worms die before changing into pupae. A single worm killed by this parasite has been known to contain over 2,000 of these little flies. The parasites complete their development in the dead worm. Figure 4, Plate IX, Page 27 shows a parasitized worm just before the emergence of the parasites, the pupa of which completely fill the skin of the cutworm and can be seen through it as little oval bodies.

Digger-wasp

The digger-wasp [6] (Fig. 18, Plate VI, Page 21) is another very interesting natural enemy of cutworms. The figure represents one of these insects carrying an army cutworm to its burrow. So interesting are their habits that the writer is giving the story of the capture and subsequent entombing of a cutworm by a digger-wasp.

On warm days in early summer these blue-black wasps can be seen hurrying over the ground, in and out of every hole, under every clod and into every possible place where a cutworm could hide. In its search many short flights are made and when running the wings are jerked nervously, while every movement of the hunter is indicative of the greatest haste.

When a cutworm is found it is immediately paralyzed, apparently by being stung. This does not kill it but renders it helpless, in which condition it remains until destroyed by the larva of the wasp.

The next act in this tragedy of nature is the finding of a suitable place to leave the worm while a site for the home of the young wasp is found. Always, so far as observed, the worm is left on some high place, such as the top of a large clod of earth or in a fork of some plant an inch or two above the ground.

Dame wasp (for it is always the female that catches the cutworms) does not believe in the old adage, "Never catch a bird until you have a cage for it," as the worm is always secured before the burrow is dug. The worm having been left in some place of prominence, the search for a suitable location to dig a burrow begins. Mrs. *Fossores* (for this is one of her names) does not consider "any old place" good enough for a home for her young. One wasp was seen to start seven burrows before finding a place entirely to her liking. The eighth location proved satisfactory and the burrow was completed. Several of the unsatisfactory attempts were made where the soil was soft and the digging easy; however, an easy job did not seem to be what the wasp was looking for. The location finally selected was in a hard beaten pathway where the digging was very difficult. Thirty minutes were consumed in the construction of the burrow. The wasp rested but once during this period and then for but a very short time, when she lay flattened out on the warm soil in the sunshine.

([4]–[6]) See explanation of "Reference Figures," page 2.

When the nest was completed the wasp wandered about for several minutes and finally went to the worm, grasped it by the throat and carried it in almost a straight line to the mouth of the burrow, where it was laid with its head toward the opening. She then entered the burrow, turned around, came out, and grasping the worm, backed into the burrow again, dragging it after her. After a few seconds, during which time the egg was fastened to the worm, the wasp reappeared, turned its head away from the mouth of the burrow, and, standing on her four hind legs, clawed dirt into it with her front feet. Every little while she turned around to ram the dirt into the opening with her head. This was continued until the mouth of the burrow was completely filled. The surface of the soil was left in such a condition that it was only with the greatest difficulty that the writer could locate the burrow.

The egg, shown fastened near the head of the worm in Figure 17, Plate VI, Page 21, gradually changes into a maggot. The forward end of this maggot, which contains the mouth, is long and pointed and during the entire feeding period remains embedded in the body of the worm. As the larva increases in size the worm shrinks until, when the grub is fully grown, nothing but its empty skin remains, as shown in Figure 16, Plate VI, Page 21. When the young wasp has exhausted its supply of food its head is withdrawn from the empty skin of the worm.

The next day or so is spent in lining its burrow with a silken cocoon, within which the grub changes to the pupa and finally into the adult wasp.

Birds

Birds are among the most effective natural checks of cutworms. The meadow lark is probably one of the most valuable, its food in May being about 24% caterpillars, the greater part of which are cutworms. Blackbirds of all species, and robins, destroy large numbers of cutworms, as do many other ground feeding species.

(b) PALE WESTERN CUTWORM

(Figs. 9, 10, 11 and 12, Plate I, Page 11)

The pale western cutworm [12] is a western species which until 1911 was not known as seriously injurious. Reported outbreaks have all occurred in the Great Plains and Rocky Mountain areas of the United States and the prairies of Western Canada.

Unlike the western army cutworm, this species does not occur in alfalfa to any extent. Fall grain, crops planted on weedy fallow land and those following grain are most apt to be injured. Seldom are crops following cultivated crops injured unless they are adjacent to infested fields. This is especially true of crops following sugar beets and potatoes.

DESCRIPTION

The Worm

The full grown worm (shown natural size, Fig. 9, Plate I, Page 11) is a dirty, pale gray color. After eating its fill of green food it takes on an olive tinge. The head and part of the first segment of the body back of it are light brown. There are usually two dark lines on the head as

(12) See explanation of "Reference Figures," page 2.

shown in the figure. The small dark spots on the segments of the abdomen, each bearing a short stiff bristle, are usually plainly visible.

Just beneath the skin of the back is an organ which fulfills the offices of the heart in the higher animals. This shows as a dark line in the center of the back running nearly the whole length of the worm. If watched closely it will be seen to pulsate in true heart fashion when the worm is alive.

The Pupa

The pupa resembles that of the western army cutworm so closely that Figure 2, Plate I, Page 11, will suffice for both. Aside from some minor structural differences the only difference is in the size. The pupa of the species under consideration is slightly smaller than that of the western army cutworm.

The Moth

Figure 10, Plate I, Page 11 represents the moth, natural size. The whole insect is lighter than the moth of the western army cutworm. The colors are chiefly delicate shades of tan and brown. These moths fly more freely during the day than those of the preceding species. On warm afternoons in fall they have been seen feeding on the blossoms of "rabbit brush" in quite large numbers.

LIFE HISTORY

The life history of the pale western cutworm is essentially the same as that of the western army cutworm. The only important differences are in the dates when feeding ceases and the changes from worm to pupa and pupa to moth take place. For a description of how and where these changes take place read those parts of the discussion of the western army cutworm under the heads "The Pupa" and "The Moth" (Page 41).

This cutworm is single brooded in Northern Colorado. The eggs, shown very much enlarged in Figures 11 and 12, Plate I, Page 11, are a little less than $\frac{1}{32}$ of an inch in diameter. The eggs are laid during September and October, and so far as known are deposited either in cracks in the soil, on lumps of soil or on the surface of the soil. Seldom, if ever, are they deposited on green plants. Dry, fallow land and stubble fields are ideal locations for egg laying.

During open, warm falls some eggs may hatch before winter sets in, but field observations indicate that the greater part of the eggs do not hatch until spring. As soon as hatched the worms begin feeding and continue to feed until the last of June or the first or second week of July. **Because of this late feeding habit late planting cannot be resorted to as a means of preventing loss, as no profitable field crop can be planted at this late date.**

The worms remain in their earthen cells for two or three weeks before the change to the pupa takes place: In about four weeks more the moth emerges.

NATURAL ENEMIES

Little is known of the natural enemies of the pale western cutworm. In all probability it is held in check by some of the same parasitic and predacious insects and birds as the western army cutworm.

(c) VARIEGATED CUTWORM

(Figs. 7 and 15, Plate VII, Page 23)

This is one of the most universally distributed of all cutworms. It is known over practically the whole agricultural world with the possible exception of Africa. At one time or another damaging outbreaks of this worm have occurred in nearly every part of its range. While, so far as the author knows, no serious outbreak has occurred in the sugar beet growing sections of the West which come within the scope of this Bulletin, yet it is always present in our fields and may at any time appear in such numbers as to do considerable damage.

This worm is a very general feeder, attacking almost any green plant. It seems to prefer cultivated plants, and feeds sparingly upon weeds, grasses and grains.

NATURE OF INJURY

The feeding habits of the variegated cutworm differ in some respects from those of the preceding species. In California it is reported as damaging young sugar beets in April.* At this time the worms spent the day buried in the soil, coming out to feed during the night and early morning. The beets were eaten off near the surface of the ground in true cutworm fashion. During the same season a later brood of worms fed upon the leaves, entirely stripping the plants of foliage. The roots were also damaged to some extent. Large numbers of these worms have been observed in Northern Colorado on the third cutting of alfalfa.

METHODS OF CONTROL

While the author has had no experience in the control of this cutworm, it would seem that during the early part of the season, before the worms have acquired the climbing habit, the poisoned bait so successfully used against the western army and pale western cutworms would be equally successful in the control of this species.

In the case of later broods or when the worms are feeding upon the leaves, spraying with Paris green will give satisfactory results, according to Mr. G. E. Bensel.* In his work in California Mr. Bensel used 2 pounds of Paris green to 50 gallons of water. To this about 1 lb. of molasses was added to make the poison adhere to the leaves. Two or three applications were required, at a cost of about 90 cts. per acre, to check the worms. A traction sprayer should be used in order to secure an even application and an economic use of the poison.

Large lantern traps were also used to catch the moths in Ventura Co., California, with very satisfactory results.

DESCRIPTION

The Egg

The eggs resemble those of other cutworms. They are deposited in clusters of from a few to as high as 50 or 60 on the twigs of trees and leaves of various plants.

*G. E. Bensel, "Control of the Variegated Cutworm in Ventura County, California." Journal of Economic Entomology, Vol. 9, No. 2 (April, 1916).

The Worm

The worm (Fig. 7, Plate VII, Page 23) is variable in color, ranging from a very pale to almost a dark brown. Some light individuals have a greenish tinge. The upper part is mottled with various shades of brown and in the darker worms some black. On each side is a conspicuous yellow stripe and above this a dark stripe broken into a row of crescent spots, as shown in the figure. The most characteristic marking is the row of yellow spots in the center of the back on the forward half of the body.

The Moth

The moth, like the worm, varies in color. The one shown in Figure 15, Plate VII, Page 23, is of the dark type, the other extreme being very much lighter, while all gradations of color between the two occur. Like the moths of most cutworms, the adult variegated cutworm flies principally during the night when it is attracted by strong lights. Advantage of this fact is sometimes taken in applying control measures.

LIFE HISTORY

As is likely to be the case with insects which range over so large a territory, the seasonal history of the variegated cutworm varies with the locality. It is known to pass the winter in every stage from the egg to the adult moth, depending upon the latitude. In Northern Colorado it probably passes the winter in the pupal stage or as a partly grown worm. There are two, possibly three, generations produced annually in the latitude of Northern Colorado. The damage is done largely by the first and second broods. The third brood, when produced, usually comes too late to do any great damage during the fall. However, these late hatched worms may hibernate over winter, in which case damage may be done the following spring.

2. WHITE GRUBS

(Figs. 19, 20 and 23, Plate I, Page 11)

White grubs are the larvae of several species of rather robust beetles commonly known as May beetles or June bugs. These beetles often enter houses at night, being attracted by the lights. At such times they fly awkwardly about, their wings making a loud humming noise. Their flight usually ends abruptly as they collide with the wall or some object in the room and fall heavily to the floor.

These insects belong to a large family, some species of which are scavengers, while others feed upon living plants. The latter do much damage to crops, especially in the Mississippi Valley and eastward.

The Sacred Beetle of Egypt belongs to this family. This beetle was held in high veneration by the ancient Egyptians. It was placed in the tombs with their dead. The members of this group we know as "tumble-bugs," from their habit of rolling about large balls of dung in which their eggs are laid. To the Egyptians this ball was symbolic of the earth and the beetle of the sun. The thirty joints of the feet were taken to represent the days of the month. It was supposed that all of these beetles were males. This was taken to symbolize a race of warriors,

a superstition which reached as far as Rome, where the soldiers wore images of the beetles as sets in their rings.

The grubs of some species lie on their backs in the soil. This is responsible for a myth of the Cherokee Indians* which runs something like this:

In the old days the beasts, birds, fishes, insects and plants could all talk and they and the people lived together in peace and friendship. As time went on the people became so numerous that they began to crowd the poor animals until they became cramped for room. Worse yet, man invented bows, knives, blow-guns, spears and hooks and began to kill the birds, animals and fishes for food and to tread upon the smaller creatures, such as frogs and worms, out of pure contempt. So the animals decided to hold a council to determine upon measures for their common safety.

The bears met first. After each had complained about how man killed their friends, ate their flesh and used their skins for robes, it was decided to begin war against man at once. Some one asked what weapons man used. "Bows and arrows," was the answer. The bears decided to try fighting man with his own weapons. One bear got a fine piece of locust wood for the bow. Another sacrificed himself for the good of his friends that his entrails might be used for bow strings. But, alas, it was found that the bears' long claws spoiled the shot. Some one proposed that their claws be trimmed. This was done and the arrow flew straight to the mark. The leader, a large white bear, objected, saying that all bears needed claws in order to climb trees. "It is better to depend upon teeth and claws that nature gave us, for it is evident that man's weapons are not for us."

The deer held council next and decided to send rheumatism upon the hunter who killed one of them unless he took care to ask their pardon for the offense.

Next the fishes and reptiles held council and decided to cause man to dream of snakes twisting about him in slimy folds or of eating decayed fish so that he would sicken and die.

Finally the birds, insects and other small animals came together in council. The grubworm was chief of the assembly. After all had made complaint about the cruelties of man they began to name the different diseases with which he should be afflicted. As disease after disease was named, the grubworm became so happy that he finally shook for joy and fell over backward and was unable to rise but had to wriggle off on his back, as the grubworm has done ever since.

When the plants heard what had been done by the animals they decided to defeat their evil designs. So each tree, shrub and herb, down even to the grasses and mosses, agreed to furnish a cure for some one of the diseases. Thus came medicine.

NATURE OF INJURY

White grubs never appear above ground but live and feed below the surface. They are naturally grass-land inhabitants, being most common in pasture and meadow land, where they feed on the roots of the grasses.

*"Myths of the Cherokee," Nineteenth Annual Report of the U. S. Bureau of Ethnology (1898).

Sugar beets, potatoes and corn are among the field crops most seriously damaged. Garden truck and strawberries often suffer heavily, also.

In the case of potatoes and sugar beets deep pits are eaten into the tubers and roots. If sugar beets are damaged when the plants are small the root is eaten off two or three inches below the surface of the ground. The plant, of course, wilts. If it is pulled the tip of the root at the point where it is eaten off will be dark in color, sometimes almost black. Wireworm injury is so similar to this that the two are easily confused. Later in the season when the beets have attained some size they may not be entirely eaten off but portions of their surface will be eaten away. Beets attacked at this time of the year usually wilt, especially in the heat of the day. Such beets are easily pulled because the grubs have destroyed most of the smaller roots. When removed from the soil, the surface will be found pitted, the pits being dark in color and rough on the surface.

The adults (beetles) of many of the injurious June bugs feed upon the leaves of various trees, mainly cottonwoods and willows in the beet-growing areas covered by this Bulletin. Injury by white grubs has been noted only in river bottoms where natural sod and the trees mentioned above are both common. **Crops following sod or crops in which much grass was allowed to grow are most apt to be injured.**

METHOD OF CONTROL

There is no known method by which an infested field can be freed of white grubs without injury to growing crops. However, measures can be taken which will reduce the injury or prevent future losses.

Pasturing with Hogs

When practical, pasturing with hogs will rid land of grubs. There is one drawback to this method, however. This lies in the fact that the giant thorn-headed worm, an internal parasite of swine, passes one stage of its life in certain white grubs. Hogs eating these grubs become infested and grubs eating the excrement of such animals become infested in turn. If no hogs have been pastured on land for at least three years, grubs in it will not contain this parasite, and hogs pastured on such land will not become infested.

Rotation

White grub losses can be reduced by practicing a proper system of rotation. Since the beetles usually deposit their eggs in fields of grass or small grain, sugar beets, potatoes or corn should not follow these crops in localities where grubs occur unless the ground is known to be free from them. Alfalfa, clover, buckwheat, peas and small grain are not damaged to the same degree as the crops mentioned above.

Plowing

Fall plowing, if done early, is a great help in destroying this pest. As the grubs burrow deep into the soil as cold weather comes on, to be effective, fall plowing must be done not later than October. Fall plowing is much more effective if followed by the disc or harrow. Plowing infested land in July or August will destroy many beetles, as the change from pupa to adult takes place about this time and the newly transformed beetles are easily killed.

LIFE HISTORY

The life histories of the May beetles are not very well known. Few records exist of the raising of beetles from the egg. In all probability most, if not all, of the injurious species occurring in the beet growing sections of the arid West have a three year life cycle. It is possible that the same species may complete its development in two years in the South, in three years in the northern tier of states, and require four in Canada.

In general, the life cycle of the white grub is as follows: The beetles lay their eggs in the soil in early summer. As soon as the young grubs hatch they begin to feed. At this time they seem to prefer decaying vegetable matter, although when very numerous they are known to attack and damage growing crops. Feeding continues until the approach of cold weather, when the grub burrows deep into the soil, where it spends the winter in hibernation. Usually the damage done during the first season of the grub's life is slight.

With the return of spring the grubs come toward the surface, where they begin a season-long campaign against the farmers' crops. It is during this second year of their lives that the grubs do the most damage. At this age the grub appears as in Figure 19, Plate I, Page 11.

Again with the coming of winter the grub burrows into the soil, returning to the surface the following spring to feed a few weeks. The change from grub to pupa takes place about the first of June. After remaining in this resting stage for several weeks the adult beetle emerges from the pupa. The beetles do not leave the soil until the following spring, however. Digging their way out of the soil during May, the beetles proceed to feed, mate and deposit the eggs for another generation of grubs.

Figure 23, Plate I, Page 11 represents the adult of a common white grub which sometimes occurs in fields in our river bottoms.

Figure 20, Plate I, Page 11 is the grub of a small species which is found in newly broken alfalfa ground and is often mistaken for the young grubs of injurious species. So far as known it feeds only upon rotting vegetable matter and not upon crops.

NATURAL ENEMIES

The white grub is preyed upon by many birds, animals and insects, which materially aid in holding it in check. The U. S. Biological Survey has found this insect in the stomachs of 60 species of common birds. Of the feathered enemies of the white grub the crow and the crow blackbird are no doubt the most important. Both of these birds will follow the plow in grub infested fields and search out the grubs exposed. The number of grubs which a crow blackbird will eat at one time is almost beyond belief. It has been reported* that one bird ate 20 grubs in about two minutes.

Skunks are very fond of white grubs. Meadow lands are often so thoroughly worked over by these animals that hardly a square yard over large areas does not contain one or more of the shallow holes from which a grub has been taken.

*J. J. Davis, "Common White Grubs," Farmers' Bulletin No. 543, U. S. Department of Agriculture (1913).

Parasitic and predacious insects, while they destroy many of the grubs, and beetles as well, are of less importance seemingly than the bird and mammal enemies of this pest. In the Farmers' Bulletin mentioned,* Mr. Davis names two wasps, "*Tiphia inornata* Say.," and "*Elis sexcincta* Fab.," and a parasitic fly, "*Pyrgota undata.*" The first two destroy the grubs and the last preys upon the beetles.

3. WIREWORMS

(Figs. 13, 14, 15, 16, 17, 18, Plate I, Page 11)

Few boys and girls grow to manhood and womanhood on the farm without becoming familiar with the "snapping-beetles," "skip-jacks," or "click-beetles," as adult wireworms are called. (Figs. 16 and 17, Plate I, Page 11, and Fig. 5, Page 52.)

Fig. 5. Adult Snapping-beetle, *Alaus oculatus.* The larvae of this beetle feed upon decaying wood.

Many a dull moment has been enlivened by the acrobatic performances of these trim, slender bodied beetles which drop as if dead, when touched. With their legs closely folded against their bodies they feign death until they think all danger is past, when they are off for cover as fast as they can travel. If they happen to fall on their backs they will spring into the air several inches, turn over, land on their feet, and are off at a run. This springing is accompanied by a sharp snap or click, therefore the names "snapping-beetles" and "click-beetles."

There are over 500 species of these insects found in the United States. The larvae of many of these live in the decaying wood of stumps and fallen trees. Many others are denizens of the soil. Among the latter are the injurious forms. These are most apt to be found in pasture and meadow lands or wherever grass is allowed to grow about the fields. A few species are known to be predacious, feeding upon other insects and often upon their own kind.

NATURE OF INJURY

During the early part of the season, especially about the time the beets are being blocked and thinned, here and there a beet will be found which is apparently dying. The leaves will be wilted, many times the outer ones being dead and dry. When such beets are pulled they will be be found gnawed off an inch or two below the surface of the ground. The end of the beet as it comes from the soil will usually be dark, almost

*J. J. Davis, "Common White Grubs," Farmers' Bulletin No. 543, U. S. Department of Agriculture (1913).

black. This wilting of the leaves, associated with the darkening of the tip where it is gnawed off, are characteristic of wireworm injury; however, the work of white grubs is very similar in the early part of the season.

Many times beets eaten off by wireworms will throw out new roots, especially if the soil is moist. Such beets develop a short sprangly root as a rule. If the soil is dry and the weather warm the injured plants usually die. This results in a poor stand if the injury is severe.

Wireworm injury to sugar beets is not so severe in the Great Plains States as it is farther east and in California. In the latter state the damage is especially severe and is due to the sugar beet wireworm, which is very numerous in the beet fields of some parts of that state.

This wireworm also damages alfalfa, corn and beans.

METHODS OF CONTROL

Because of the great similarity between the habits and life history of white grubs and wireworms, many of the same methods of control may be used against both.

Rotation

As already stated, wireworms are most likely to be found in abundance in **pasture and meadow lands.** When such lands are broken up and planted to field crops those least apt to be badly injured should be put in the first season. **Row crops, such as sugar beets, corn or potatoes, suffer most severely on infested ground.** While the small grains are sometimes severely injured they are not as a rule so badly damaged as corn and root crops.

Short rotations in which the land is not allowed to remain in grass for any length of time will prevent the increase of wireworms, as the females prefer grass lands as places to deposit their eggs.

Plowing

Early fall and late summer plowing will kill many newly transformed beetles and pupae, especially if the surface is thoroughly worked with the disc or harrow.

Seed Treatment

Sometimes wireworms injure seed corn before it germinates, thus causing an almost total loss of stand in severe cases. Treating the corn before planting by coating it with gas tar and dusting with Paris green will almost entirely prevent loss, according to tests conducted by Dr. H. T. Fernald in Massachusetts in 1908 and 1909.

Poisoned Bait

Many poisoned baits have been tried, but with very little success.

DESCRIPTION

The Worm

Wireworms vary in form and color as well as size. The species most injurious to sugar beets resemble Figure 13, Plate I, Page 11. This is the larva of the "click-beetle" (Fig. 16, Plate I). Figure 14, Plate I, is an outline drawing of the last segment of the body of this worm. The notch in the center is characteristic of many of our injurious wireworms. Figure 18, Plate I represents another species often found in our fields.

The Pupa

The pupal stage (Fig. 15, Plate I) is spent in an oval cell in the soil. The figure represents the pupa on the beetle shown in Figure 16, Plate I.

The Beetle

The beetles of this group are characterized by the freely moving joint between the thorax and abdomen and by their power to spring into the air when placed on their backs.

Our most common species [5] (Fig. 16, Plate I) is dark brown. Figure 17, Plate I, represents a smaller, lighter colored species.. The drawing to the right of the colored figure is the natural size of this beetle.

LIFE HISTORY

The life history of the soil-inhabiting species of wireworms is very similar to that of the white grubs. The eggs are laid in the soil. Usually meadows, pastures or other grass covered lands are selected by the females as places to deposit their eggs.

Two or three years are required for the worms to reach maturity. Feeding takes place each season. When mature the worm forms an oval cell in the soil in which the change to the pupal stage takes place. This change occurs during the summer months. In the course of a few weeks the adult beetle emerges from the pupa.

Most of the newly transformed beetles remain in the soil until the following season. However, a few leave their pupal cells soon after emerging. During the following winter these beetles hibernate under dead leaves, crop refuse or other material which furnishes suitable protection against the cold and moisture.

NATURAL ENEMIES

Ground Beetles

Wireworms are unusually free from attack by parasitic insects, but the predacious ground beetles destroy many of them. Several species of the Genus *Calosoma*, one of which is represented in Figure 2, Plate IX, Page 27, and their larvae, feed freely on this pest.

Birds

Many species of birds are very effective in destroying the beetles. The ill-famed crow is a noted wireworm destroyer. The food of the California shrike, or butcher-bird as it is sometimes called, is known to consist largely of adult wireworms during certain seasons of the year and where these are abundant. From 90% to 95% of the food eaten is composed of these beetles at such times, according to observations recorded by John E. Graf, in Bulletin No. 123, Bureau of Entomology, U. S. Department of Agriculture.

Skunks

Skunks, which are so effective in the destruction of white grubs, devour large numbers of wireworms as well as the adult beetles. In 1914 the writer examined a quantity of excrement of the little, spotted skunk. No evidence of any other animal food aside from insects was found. Over 10% of the insects eaten were wireworms and click-beetles.

(5) See explanation of "Reference Figures," page 2

B. SUCKING ROOT FEEDERS

I. SUGAR BEET ROOT-LOUSE

(Figs. 1 to 9, 11 to 13, 16 to 18, Plate II, Page 13)

Because of its universal distribution in the sugar beet growing sections of the West and the difficulty of controlling it, the sugar beet root-louse presents one of the most serious insect pest problems with which the beet growers and factory people have to contend.

NATURE OF INJURY

Visible effects of root-louse injury on the above-ground parts of the sugar beet do not appear until the number of lice becomes very great. At such times the color of the beet leaves changes from a dark to a yellowish green. This change in color alone must not, however, be taken as proof that a crop is being greatly damaged by root-lice. Sugar beets, especially when grown on light soil or watered too heavily, will turn light in color in the latter part of the season when not infested with root-lice. When the lice become very numerous the beet leaves wilt as though the crop were suffering from lack of water. Often the beets become so shrunken as to be loose in the ground and very much wrinkled. Such beets are very limber and can be bent almost double without breaking.

The above is descriptive of exceptional cases. Whether effects are visible or not, if lice are present, on the surface of the roots and in the soil surrounding them will be found a whitish, mold-like substance. Intermingled with this and covered by it will be seen many small, wingless lice of a yellowish white color (Fig. 9, Plate II, Page 13), and if the season is well advanced some darker winged lice (Fig. 7, Plate II, Page 13) as well.

The effect of lice on live stock is so well known that no one expects a lousy animal to make normal growth or put on fat. The loss of blood and possibly the irritation caused by the feeding of the lice stunt it and produce a very scrubby and inferior animal. The effect of lice on a sugar beet may be compared with that of lice on livestock. The lice take up the sap of the beet and the feeding irritates it. The combined effect of these two things is a small, stunted beet and one low in sugar content. Of course quite satisfactory yields and sugar contents are possible even though the beets are lousy. Nevertheless, nothing is more certain than that had they not been lousy both would have been higher.

Carefully conducted tests show that infested beets contain from $\frac{3}{4}\%$ to 1% less sugar than uninfested beets in the same field. Also, the purity of juice of such beets is from 1% to 2% lower than uninfested beets. The average infestation reduces the yield by more than 1 ton per acre. In very severe cases the beets are killed or made worthless for factory purposes.

METHODS OF CONTROL

There is no known means of entirely preventing sugar beet root-louse losses. However, if the crop is properly handled they can be greatly reduced.

Irrigation

It has been shown by Mr. J. R. Parker of the Montana Experiment station*, that the sugar beet root-louse does not multiply so rapidly in moist as in dry soil. Experiments conducted by him on The Great Western Sugar Company's farm at Edgar, Montana, and on the Government Reclamation Project at Huntley, Montana, show that **fields irrigated during the migration of the lice from the cotton-wood trees to the beet fields are much freer from root-lice at harvest than fields not irrigated until later.**

Migration begins about the 10th of June and is at its height about the 20th of the month in the latitude of Denver, Colorado. In the latitude of Billings, Montana, the height of migration is probably reached six to eight days later. Since the losses due to this insect are proportional to the number of lice present and feeding on the crop, anything which reduces their number reduces the loss as well. Frequent irrigations during the growing season reduce the infestation and also increase the yield of beets.

In a leaflet issued by Mr. Parker and circulated by The Great Western Sugar Company at Billings, Montana, the results of several years' work in the control of the sugar beet root-louse, show that there are 56.2, 46.6 and 25.6 beets out of every 100 infested where two, three and five irrigations respectively were applied.

The sugar content was 15.8%, 17.1% and 17.2% for two, three and five irrigations respectively.

The gross returns per acre were $82.27 for two, $85.61 for three, and $96.07 for five irrigations.

To some, early irrigation may seem like "jumping from the frying pan into the fire," since it is quite generally believed that early watering is detrimental to sugar beets. Quite to the contrary it has been found that irrigating as early as June 22nd produces better results in yield and per cent of sugar in the majority of years. It is a fortunate coincidence that early irrigation gives best results in just the years which are favorable for the development of root-lice; i. e., years when the winter and early summer are dry.

Through experiments conducted on The Great Western Sugar Company's Experimental Farm at Longmont, Colorado, it has been found that, as an average of six years tests, irrigating as early as June 22nd to 25th has produced a yield of 14.66 tons per acre and 16.05% sugar, while beets irrigated the first time July 5th to 10th gave a yield of but 14.23 tons per acre and a sugar content of 15.84%. Both the early and late irrigated beets were watered three times each season. **The gross returns were $87.29 per acre for the early and $83.80 for the late irrigated beets, without any greater expenditure of labor or water for the increased returns due to early irrigating.**

Fall and Spring Irrigation; Plowing

Fall or early spring irrigation will no doubt destroy most of the lice in the soil. However, if the destruction of the lice is the only reason

*"Life History of the Sugar-beet Root-louse, *Pemphigus betae*," Journal of Economic Entomology. Vol. 7, No. 1 (1914).

for this irrigation it is doubtful if the results will warrant the use of the water. During the process of plowing and working down the seed bed, the majority of the hibernating lice are destroyed.

Rotation

While quite a number of lice live over from season to season in the soil of old beet fields, yet they are of little importance as compared with the lice from the narrow-leaf cottonwood trees as a source of infestation. **For this reason rotation is of very little avail in preventing losses.** The results of a survey covering 80,000 acres, made in 1916, showed that 83 beets out of 100 were infested with root-lice where sugar beets were grown on old beet ground and 82 out of 100 where they followed all other crops. This proves conclusively that rotation will not prevent root-louse losses. The presence of lice in the soil in the spring is no reason why such fields should not be planted to beets provided they are otherwise fit.

The results of the survey mentioned above show quite conclusively that the destruction of all narrow-leaf cottonwood trees within the beet growing sections will reduce the damage done by the sugar beet root-louse. Therefore, the cutting of these trees is strongly to be recommended. However, it will not entirely free beet fields of this pest, since many lice reach them from the foothills and canyons.

DESCRIPTION AND LIFE HISTORY

Mention has already been made of winged lice on the beet roots in the fall. During warm, sunny autumn days swarms of these little winged lice leave the beet fields and fly to the narrow-leaf cottonwood trees.

About every narrow-leaf cottonwood with the rays of the sun glistening on their wings, thousands of lice sway in and out among the branches. One by one they alight to go hurrying up and down as if fearful lest the oncoming winter overtake them before suitable homes for their young have been found.

In deep crevices and under loose pieces of bark these winged migrants from the beet fields deposit their minute, yellowish young. These are of two kinds, tiny little females (Fig. 18, Plate II, Page 13), and still smaller males (Fig. 16, Plate II). (Note the minute representation of the actual size of these lice, shown at the left of the figures.) Almost microscopic in size, mouthless and living but a few days, their sole object in life is to produce the solitary egg which each female lays. This accomplished the female dies, the male having died shortly after mating took place.

Figure 13, Plate II, Page 13, is the antenna of Figure 16, Plate II, Page 13, greatly enlarged.

The eggs, one of which is shown very much enlarged (Fig. 17, Plate II), are about $\frac{1}{64}$ of an inch long and one-fourth as broad. Snugly tucked away in some crevice of the bark they remain until the warm days of spring cause the buds to swell, when from each egg a small, dark louse (Fig. 2, Plate II, much enlarged) emerges. As soon as hatched this little louse starts in search of an opening bud. When one is found

it crawls in among the expanding leaves and begins to feed upon the upper surface of one close to the midrib. This feeding causes a depression to form and the leaf to turn light in color (Fig. 1-A, Plate II).

In the course of a few days this depression has become a swelling on the under side of the leaf (Fig. 4, Plate II), which is now entirely closed on the upper side (Fig. 3, Plate II). In this gall, as the swelling is called, the little louse is securely protected from inclement weather and the sharp-eyed birds as they flit among the branches. Both the gall and the louse increase in size for some time, until the former appears as in Figure 5, Plate II, and the louse, which is called a stem-mother, as shown in Figure 6, Plate II.

This rotund stem-mother gives birth to several living young daily during the next month or six weeks. If opened about the middle of June the gall will be found to contain many pale lice all surrounded by a whitish substance. This waxy material is secreted by glands and escapes through what are called wax-pores, which are arranged in rows across the body of the insect. These appear as light, round spots on the back. (Fig. 6, Plate II).

The young of the stem-mother do not resemble her in form, being slender of body and at first wingless. As they grow older wing pads appear on their shoulders. After shedding their skins several times, growing darker with every succeeding molt, the last larval skin is shed and a delicately winged louse (Fig. 7, Plate II) emerges. The antenna of this winged louse is shown in Figure 8, Plate II.

About the time the first winged lice appear the mouth of the gall begins to open. Through this opening the winged lice escape and fly or are blown by the wind far and wide among the beet fields, where they settle on the beets and deposit their young, which immediately descend to the ground and take up their abode on the beet roots. All the young of the winged migrants from the cottonwood trees are wingless and when full grown appear as shown in Figure 9, Plate II.

The antenna of the wingless lice which are found on the beet roots is shown in Figures 11 and 12, Plate II.

These wingless lice give birth to still more wingless lice. This goes on until several generations and hundreds of lice have been produced on the beets. Then with the return of fall some of the lice on the beet roots develop wing pads like those of the young of the stem-mother in the gall. After acquiring wings these lice are known as the fall migrants.

These migrants return to the narrow-leaf cottonwoods and there deposit their young. Thus we have followed the lice from the galls on the cottonwood trees to the beet fields and back again to the cottonwoods.

Not all of the lice become winged in the fall, however. Some wingless ones remain over the winter in the soil, where they hibernate in earth-worm burrows and other openings. Thus we see that nature has provided two means of carrying the beet root-lice over the winter: the hibernating lice in the soil, and the eggs in the crevices of the cottonwood bark.

NATURAL ENEMIES

While in the galls a bug* (Fig. 14, Plate II, Page 13) preys upon the lice. In the beet fields the little lady-beetle [11] and its larva (Figs. 10 and 15, Plate II, Page 13) feed upon the root-lice. This larva, which is not very much larger than a good sized louse, secretes a white, waxy substance with which its body is covered, making it resemble to a remarkable degree one of the lice upon which it feeds. The pupa of this beetle (Fig. 14, Plate VII, Page 23) is surrounded by the cast larval skin and white flocculent coating.

The larvae or maggots of the Syrphus-fly [14] (Fig. 13, Plate VI, Page 21) do their part in destroying this pest.

Every season large numbers of the lice are killed by a fungous disease.** This fungus develops within the lice and finally causes their death. Were it not for these natural checks the damage caused annually by the beet root-louse would be far greater than it is now.

Slender, yellowish-white maggots are often seen among the lice on beet roots. These are the larvae of a small, striped fly‡ (Fig. 14, Plate VI, Page 21). Recent investigations† show that these maggots are very effective in destroying the beet root-lice. During the latter part of the season small, oval, brown bodies will be seen among the lice also. These have often been mistaken for the eggs from which the lice hatch. Instead of being root-louse eggs they are the thickened larval skins within which the maggots change into the flies mentioned above.

2. SUGAR BEET NEMATODE

(Figs. 8, 9 and 10, Plate III, Page 15)

Quite early in the history of the beet sugar industry in Europe it was noticed that the yield of sugar beets was steadily dropping off in certain districts. In spite of the efforts of the growers to maintain the yield by using fertilizers, and in spite of their increasing knowledge of the handling of the crop, the tonnage secured was so unsatisfactory that the growing of sugar beets was discontinued on many fields.

Many theories were advanced in explanation of this condition. The most prevalent and generally accepted of these attributed the trouble to an exhaustion of the mineral plant foods of the soil.

It was noticed that those fields where beets had been grown continuously for several years were most affected. This led the Germans to give the name "Rübenmüdigkeit," or "beet weariness," to this malady.

A German scientist named Kühn was first to associate the soil inhabiting eelworm or nematode (*Heterodera schachtii*) with this trouble.

The sugar beet nematode so far has been found only in a few well defined localities within the territory in which The Great Western Sugar Company operates.

*Authocoris melanocerus.
**Empusa aphidis.
‡Chloropisca glabra.
†J. R. Parker, "Life History and Habits of *Chloropisca glabra* Meign.," Journal of Economic Entomology, Vol. XI, No. 4 (1918).
([11-14]) See explanation of "Reference Figures," page 2.

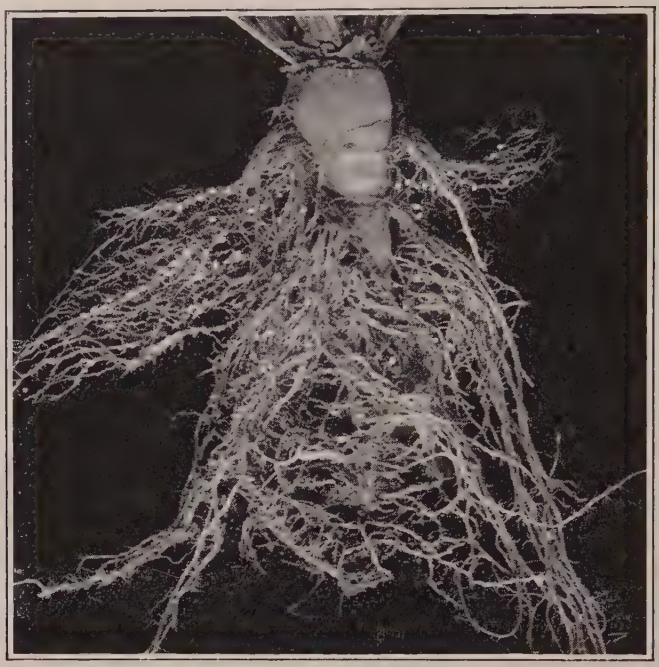

Fig. 6. A Sugar Beet infested with Sugar Beet Nematodes. The white bodies of the female nematodes can be seen clinging to the rootlets.

Fig. 7. A Sugar Beet affected with Curly-top, showing the characteristic dense mass of rootlets. (After C. O. Townsend, Farmers' Bulletin No. 122, U. S. Department of Agriculture.)

NATURE OF INJURY

The young sugar beet nematodes search out a beet root, and by piercing it with their strong spear-like mouth parts, embed themselves within the tissue. They then begin to feed upon the juices of the beet.

Effect on Roots

The presence of the nematodes causes an irritation of the roots. Because of this irritation, and because the sap is consumed by the nematodes, the roots are unable to carry the water and plant food to the beet, and the growth of the plant is interferred with.

In an attempt to overcome this trouble the beets send out many new rootlets from the root seams at each side of the main root. In Europe these beets have been called "bearded roots" or "hunger roots." Such beets (Fig. 6, Page 60) resemble the "whiskered beets" suffering from a severe attack of the disease known as "Curly-top" (Fig. 7, Page 60).

If carefully removed from the soil, the rootlets of infested beets will have many minute, pearly-white bodies clinging to them (Fig. 9, Plate III, Page 15). These are the mature female nematodes.

In extreme cases the weakened roots become infested with fungi and bacteria which cause them to rot or the plants die because of lack of nourishment.

Effect on Leaves

The presence of nematodes becomes apparent in the appearance of the leaves as the season advances. The foliage of the infested plants turns light in color, becoming a yellowish green, or they have the dull, gray-green color of beets suffering from lack of water. The leaves wilt and finally lie flat on the ground, failing to recover during the night. The outer ones finally die. The growth of the inner leaves is seriously interfered with, and in severe cases they die also. If the beet does not succumb to the attack, the new leaves produced fail to attain normal size and are often much curled and distorted. Late in the season, beets which have survived the attack are often a darker green than their uninfested neighbors.

Effect on Sugar Content

Not only is the size of the roots and leaves of the beets affected but the sugar content is greatly reduced as a result of the nematode attack. For example, moderately infested beets contained 11.35% sugar and badly infested ones only 8.4% in a field where healthy plants had a sugar content of 14.9%.*

HOW NEMATODES SPREAD

By Their Own Movements

Sugar beet nematodes have the power of increasing by their own movements the area infested. In certain stages of their development and under favorable conditions they can travel considerable distances in the soil. The ravages of this pest have been known to be extended from 50 to 75 feet each season in this way.*

*Harry B. Shaw, "Control of the Sugar-Beet Nematode," Farmers' Bulletin No. 772, U. S. Department of Agriculture (1916).

Carried by Irrigation Water

Irrigation water passing over infested areas carries many nematodes to uninfested localities with the soil washed away from these areas.

The use of factory waste water for irrigation purposes has resulted in spreading this pest over large areas in those localities where the nematodes exist.

Carried by Implements, People and Live Stock

Nematode infested soil is often carried from infested to uninfested fields on the farm implements used in their cultivation.

The wagons used in hauling a crop from infested fields or in hauling manure onto such fields often carry the nematodes to other fields.

Work animals or stock allowed to run on infested land, as well as people, spread this pest by carrying the eelworm in the soil clinging to their feet.

In Manure of Animals

The sugar beet nematode does not pass through the digestive organs of sheep alive. There seems to be no evidence that this is true of other farm animals. It is therefore quite possible that nematodes may be carried in the manure of other animals, and if beet tops on infested land are to be pastured, sheep should be used for this purpose.

METHODS OF CONTROL

The fact that the sugar beet nematode is a really formidable pest, if allowed to spread, cannot be too strongly impressed upon the minds of all beet growers, especially as it occurs in damaging numbers in several beet growing sections of the United States, including a small area in Colorado.

Since there are no known methods of entirely freeing the soil of nematodes which can be used in field practice, the adoption of proper precautions to prevent their introduction into new fields is of the greatest importance. Once this eelworm is established, the prevention of its spread is no less important than the establishing of a system of crop rotation which will check its multiplication.

How to Prevent Spread of Nematodes

(1) No waste water should be allowed to run from infested to uninfested fields.

(2) In infested areas, factory waste water should not be used for irrigation purposes unless first properly treated with lime.

(3) All implements used in working infested land should be very carefully cleaned by removing all soil from them before they are used in uninfested fields. This includes the cleaning of wagon wheels.

(4) The feet of persons and work animals should be thoroughly cleaned before going from infested to uninfested fields.

(5) Live stock should not be allowed to run on infested land unless it is to be confined there until removed to market.

(6) Beet tops from infested land should not be removed but should be pastured on the land where grown.

(7) The manure of animals fed on beet tops from infested land should not be used on uninfested land.

How to Check Multiplication of Nematodes

Field Surveys

All suspected fields should be thoroughly examined, so that the exact location and extent of infested areas may be known. That such surveys of suspected lands be made is of the greatest importance.

Local Treatment

If the infested areas are small, local treatment may be all that is necessary. All plants on the area should be pulled, together with those from a strip several feet wide all around it. These should be destroyed by burning on the spot.

A trench about one foot deep and one foot wide should then be dug around the infested spot and this filled with quick-lime. The surface of the infested area should be covered with lime an inch or two deep and this thoroughly mixed with the soil. Frequent mixing of the limed soil will add to the effectiveness of the treatment.

Pasturing with Sheep

Pasture the beet tops grown on infested land to sheep, rather than to other stock, as the nematode in the tops eaten will thus be destroyed, and will not be returned to the soil through the manure.

Rotation

The sugar beet nematode infests the roots of many weeds and cultivated crops. The following list of plants known to be subject to attack is taken from Farmers' Bulletin No. 772 of the U. S. Department of Agriculture.

Alfalfa	Dandelions	Pinks
Allseed	Foxtail, Green	Potatoes
Barley	Hemp	Radishes
Beans, Dwarf Pea	Hops	Rape
Beans, Lima	Kale	Rutabaga
Beets, Garden	Kohl-rabi	Rye
Beets, Sugar	Lentils	Sorghum
Cabbage	Lupine, Yellow	Spinach
Cabbage, Chinese	Meadow-grass, Annual	Sunflower
Cauliflower	Meadow Oat-grass, Tall	Timothy
Celery	Mustard	Turnips
Clover, Crimson	Oats	Vetch
Clover, White	Parsnips	Wheat
Corn	Peas, Garden	
Cress	Peas, Sweet	

In the above mentioned bulletin the author lists the following crops as being available for Colorado and neighboring states for rotation on infested land:

Cow Peas	Asparagus
Soy Beans	Lettuce
Sweet Clover	Cantaloupe
Rye	Barley
The Millets	Wheat
Tomatoes	Cucumbers

Potatoes

Potatoes are often slightly injured.

DESCRIPTION AND LIFE HISTORY

In the course of its development the sugar beet nematode passes through four forms or stages: the egg, two larval stages, and the adult.

The Egg

Each adult female produces from 300 to 400 eggs. These are colorless and broadly oval or kidney-shaped. They are extremely small, being only about $\frac{1}{300}$ of an inch long.

The Larval Stages

The young nematodes, or larvae, are very active, threadlike creatures. Being colorless and almost microscopic in size, they are seldom noticed in the field.

It is in the first larval stage that the nematodes enter the tissue of the beet roots. The first larval skin is cast shortly after entering the beet and the larva takes on a more robust form.

The Adult

With a second molt the nematode becomes an adult male (Fig. 10, Plate III, Page 15), or female (Fig. 8, Plate III, Page 15).

The Brown-cyst Stage

As cold weather approaches or conditions become unfavorable for the development of the females, certain individuals pass into a resting or preservation stage which is known as the brown-cyst stage.

In the cyst form the female passes the winter or the period of unfavorable conditions protecting the eggs until conditions become favorable for further development. With the change of conditions the eggs begin to hatch. They do not all hatch at once, however, but may continue to do so for long periods that may extend over several years.

3. ROOT-KNOT NEMATODE OR GALLWORM

This nematode, which is very closely related to the sugar beet nematode, seriously interferes with the growing of sugar beets in some localities.

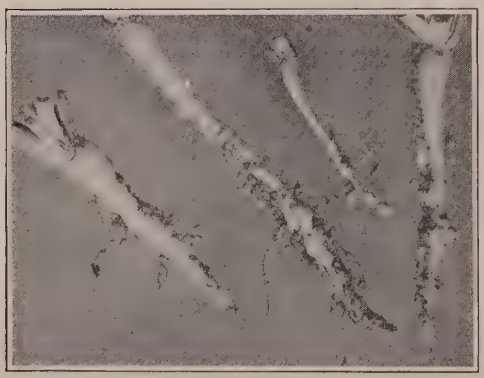

Fig. 8. Small Sugar Beets Infested with the Root-knot Nematode. The bead-like swellings on the small roots and the enlargements of the main root are caused by the nematodes.

This nematode has been found in the Sterling, Brush, Ft. Morgan and Scottsbluff districts.

NATURE OF INJURY

The roots of infested plants present a very characteristic appearance. The presence of the females and larvae in a root is indicated by irregular swellings (Fig. 8, Page 64), caused by the irritation set up by these eelworms.

METHODS OF CONTROL

Prevent Spread of Nematodes

In order to prevent the spread of this pest, the same precautions should be observed as in the case of the sugar beet nematode (See page 62).

Potatoes grown on infested land should not be used for seed, as the nematodes pass the winter within the tubers.

Such plants as tomatoes, cabbage, strawberries, kale, sweet potatoes, asparagus and horse-radish should not be taken from infested soil and transplanted in nematode free fields.

Nematode Eradication

There is no practical means of entirely eradicating the gallworm in large fields. In the case of hotbeds and greenhouses soil fumigants can be used, but these are too expensive for field use.

Rotation

The most practical method of reducing the numbers of nematodes is to rotate with such crops as are not attacked. Mr. C. S. Scofield* gives the following list of crops as suited for planting on infested soil:

Barley	Sorghum
Oats	Milo
Wheat	Kafir
Rye	Timothy
Corn	Red Top

The value of growing the resistant crops named above is strikingly illustrated by the results of a survey of five large areas in which all sugar beet fields infested with the root-knot nematode were located and a record secured of the crop grown on all fields, both infested and uninfested the year previous. It was found as the per cent of resistant crops grown increased, the per cent of infested beet fields decreased. These figures are given in the following table:

Area	Total fields examined	% of total infested	% of total growing nematode resistant crops
A	366	58.47	5.19
B	480	51.87	6.66
C	768	28.77	9.77
D	671	2.08	12.09
E	676	1.03	28.06

LIFE HISTORY

During the greater part of their lives these worms remain embedded within the tissue of the roots of their host plants.

Upon reaching maturity the fertilized females begin the production of eggs. Some of these hatch within the body of the parent, the young ultimately escaping into the surrounding tissue of the host plant. Others are laid at the rate of ten or fifteen daily.*

*"The Nematode Gallworm on Potatoes and Other Crop Plants in Nevada," Circular No. 91, Bureau of Plant Industry, U. S. Department of Agriculture (1912).

Shortly after the larvae hatch they escape from the root of the host plant and spend a time in the soil. Soon they search out the root of a suitable plant and burrow into it, where they feed upon its sap, causing the characteristic swellings already mentioned.

The nematode gallworm lives from season to season embedded in the tissue of the host plant either in the egg or larval stage. The life of the adult is only a few weeks under favorable conditions.

Plants and crops subject to severe infestation which should never be planted on infested land:*

Beet	Pumpkin	Cowpea
Carrot	Potato	Rape
Celery	Salsify	Soy bean
Cucumber	Squash	Catalpa
Egg plant	Tomato	Cherry
Lettuce	Watermelon	Elm
Muskmelon	Clover	Peach

Plants subject to attack but not seriously injured by nematode gallworms: These should not be planted on infested land as they will serve to keep the worms alive.*

Alfalfa	Cauliflower	Kale
Vetch	Garden pea	Onion
Sweet clover	Horseradish	Radish
Asparagus	Strawberry	Spinach
Cabbage	Lima bean	Sweet potato

Crops suited for planting on infested land:*

Barley	Corn	Kafir
Oats	Sorghum	Timothy
Wheat	Milo	Red top
Rye		

*C. S. Scofield, "The Nematode Gallworm on Potatoes and Other Crop Plants in Nevada," Circular No. 91, Bureau of Plant Industry, U. S. Department of Agriculture (1912).

CHAPTER III

LEAF FEEDERS

Either because they feed exposed to the view of the most casual observer or because their work is such as to attract general attention, the leaf-feeding insects are much more universally known to the layman than the root-feeding insects. In a general way the methods of controlling this class of insects are common knowledge also. However, this knowledge is of a superficial nature; that is, it is general instead of specific. This lack of knowledge of the particular insect involved has led to much waste of money, energy and material, either because the wrong remedy has been applied or the right one was not applied in the correct way or at the right time.

A. BITING LEAF FEEDERS

(Caterpillars, Beetles, Grasshoppers, Crickets, Leaf-miners)

1. LEAF-EATING CATERPILLARS

The young of moths or millers and butterflies are known by the general name of caterpillars. In size, shape, color and body covering they differ greatly in different species.

Some are but a fraction of an inch in length, while others attain a length of six or seven inches. For the most part caterpillars are cylindrical, being several times as long as thick. Some are grub-like in form and others resemble dead leaves or twigs in shape and color. The bodies of many are bare, those of others are covered with long hairs. In some species these hairs are connected with poison glands. If these caterpillars come in contact with the bare hands or face the sensation is very similar to that caused by the sting of nettles, only more severe. Some caterpillars are really formidable in appearance because their bodies are covered with large spines or spine covered tubercles.

In the kinds of food eaten, caterpillars are as variable as in shape, size or color. Some bore in the wood of trees, others feed upon hair, wool, horn and like substances. A few feed upon scale insects and the larvae of borers. Several species attack growing fruits, while others destroy stored fruits and grains. The species with which we are most concerned, and which are discussed in the following pages, feed upon the leaves of plants. Among this class are to be found some of the worst enemies of cultivated crops.

(a) SUGAR BEET WEBWORM

(Figs. 3, 4, 5, 6, 8, 9, 10, 11, Plate V, Page 19)

The sugar beet webworm is one of the most destructive leaf-eating insects attacking the sugar beet. Like many of our most injurious insect pests, it was introduced into this country from the Eastern Hemisphere, appearing first on the Pacific coast. In 1869 it damaged beets in Utah.

Since that time it has spread over the entire sugar beet growing areas of the country.

The worst outbreaks of webworms which have occurred in the territories in which The Great Western Sugar Company is operating took place in 1918 and 1919. During the season of 1918, the June and August broods both caused great damage. Some fields were injured by both broods.

An accurate statement of the acres damaged in 1918 and the degree of damage was reported by the fieldmen of The Great Western Sugar Company. These reports show that 31,000 acres were injured. The first brood injured 5,500 acres and the second 25,500 acres. Over 7,000 acres were damaged to the extent of two tons per acre, over 7,000 acres to the extent of one ton per acre and nearly 15,000 acres to the extent of $\frac{1}{4}$ ton per acre. The total loss to the growers and the industry was not less than 26,450 tons of beets. These at $10.00 per ton, the price in 1918, represents a money loss of $264,500. Over 16,000 acres were sprayed with Paris green at the average rate of 4 pounds per acre, and much loss thus prevented. This required 84,000 pounds of Paris green, much of which was furnished the growers at a reduced cost per pound by The Great Western Sugar Company.

This loss could have been very much more reduced if all growers had realized in time that there was danger and had had themselves properly prepared. **Too late spraying was responsible for much of the loss.**

As this bulletin goes to press the campaign against the first brood of 1919 is drawing to a close. This brood, which is the largest known in the history of sugar beet growing in the United States, covered practically all beet growing areas in Colorado, Nebraska, Montana and Wyoming.

In order to assist the growers in combating it The Great Western Sugar Company purchased several hundred traction sprayers and distributed about 700,000 pounds of Paris green in its territories. Had it not been for this assistance the loss to the growers would have far exceeded that caused by both broods of 1918.

NATURE OF INJURY

Webworms injure sugar beets by destroying the leaves. This retards the growth, thus reducing the yield and sugar content. All other things being equal, the loss is quite proportional to the loss in leaves. The greater the amount of leaf surface destroyed, the greater the loss. On the other hand, the losses depend somewhat upon the time of season when the damage is done, also upon the weather condition immediately after it is done.

Small beets may be killed outright if the leaf surface is so small that the worms attack the crowns. Larger beets may have their leaves entirely eaten off but recover by putting out new leaves. (See Fig. 9, Page 69, and Fig. 10, Page 70.)

The first indications that a crop may be injured by the sugar beet webworm is the appearance of the moths (Fig. 11, Plate V, Page 19) in the field. These moths are active and easily disturbed during the day. When present they will be noticed flying ahead of the cultivator or of one walking through the field. Their flights are short and jerky and they usually alight on the under side of a leaf or on the ground. Catch one

of the moths and compare it with the figure. If it is the same then look for the eggs, continuing to do so for several days. Call the attention of the Sugar Company's fieldman to the moths and get his advice.

The eggs will be found on the under side of the beet leaves, on lamb's-quarters or on Russian thistle if these weeds are growing in the field. Of a pearly-white color and about the size of a small pin-head, they are not easily seen unless careful search is made for them.

Fig. 9. Sugar Beet badly damaged by Webworms

Even though no eggs can be found, do not assume that all danger is past. Often the eggs are overlooked and the first indication you have that your crop is infested is the presence of newly hatched worms hanging from the under side of the leaves by a short web. These can best be seen by getting down near the ground and looking up and down the rows. Both the worms and web are light colored and not very easily seen unless the light is just right. Looking away from the sun makes them more easily discerned.

Picking leaves at random over a field and noting the number of eggs or young worms present is a very good way of estimating the possibility of damage in the near future. Great care must be taken not to underestimate this possibility, however. One or two worms or eggs on one-half to three-fourths of the leaves indicate the presence of enough worms seriously to injure the crop later. As some of the worms drop from the leaves when they are broken off, the worms seen do not represent all present.

Very often a few eggs in one part of a field indicate that in some other portion there are many more. Not infrequently the moths lay eggs by the hundreds and thousands over a very small area. This is quite as apt to be in the center of the field, or at least some distance from the border, as near the edge of the field. All weedy spots should be carefully examined and the weeds removed as soon as possible, as these are often the places where the injury starts and spreads to the entire field.

It is hard for a person who has not seen a severe outbreak of webworms to realize that what appears to be but a few small worms is capable of causing the loss of several dollars worth of beets. This fact has been the cause of a great deal of the loss in the past.

If eggs or young worms are found it is time to get your spray machine out, or your neighbor's if you do not have one of your own, and provide a supply of Paris green ready to apply as soon as the eggs begin to hatch.

Fig. 10. Sugar Beets badly damaged by Webworms

As the young worms feed entirely on the under side of the leaves for several days after they leave the eggs and do not eat away the upper surface, their presence is not suspected, many times, until they are so far developed that much damage is done before they can be controlled.

When first hatched the worms are so small that their capacity for doing damage is limited. As they increase in size their appetites become almost insatiable. The rapidity with which they will completely strip a beet field of leaves is almost beyond belief. Each worm will eat several times its own weight of beet leaf every day. So rapid is their work that although there is no apparent injury today, tomorrow or the next day large spots in the field may be completely defoliated.

These spots very often occur in the center of the field, thus they are overlooked unless it happens that the grower is cultivating or irrigating at the time.

Careful watch should be kept of the beets during the last half of June and the latter part of July and early August. Examine the under side of the beet leaves every day or so.

If young worms are present small pits will be eaten into the lower surface of the leaves. In case such pits occur the little whitish-yellow worms should be found not far away. If the worms are several days old they will be greenish in color, appearing more like the full grown worm (Fig. 6, Plate V, Page 19). At this age they will be found on both sides of the leaves. The edges of the leaves will be eaten away, leaving them ragged, or the entire leaf will be eaten with the exception of the heavy veins. The young leaves at the heart of the beet are usually the last eaten.

Fig. 11. Field of Sugar Beets showing Work of the Sugar Beet Webworm. Bare areas were weedy when eggs were laid. Balance of field was free from weeds.

Sometimes the worms will be concealed in webs spun over the leaf, usually near its base. In case small, roundish, dark colored pellets are seen on the leaves, a webworm or some other leaf-eating caterpillar is present. The culprit should be located and his identity established.

METHODS OF CONTROL

Destruction of Weeds

The sugar beet webworm moth shows a particular liking for lamb's-quarters and Russian thistle as plants on which to deposit its eggs. For this reason if these weeds are abundant in a field of beets the crop is apt to be damaged by webworms if the moths are at all numerous in the vicinity. Volunteer alfalfa is also a menace to the crop.

The effect of allowing weeds to grow in a crop of beets is strikingly illustrated by the cut on page 71 (Fig. 11).

At blocking and thinning time this field was quite free of weeds except a strip running entirely across the picture from right to left and indicated by the bare spots at either side. The hand labor began thinning before the webworms appeared, cleaning out the rows, including the center portion of the weedy strip, but leaving the weeds in the sections at each end represented by the bare spots. They then moved to another part of the field. In the meantime the webworm moths deposited thousands of eggs on the weeds left.

When the labor returned to this part of the field both the weeds and the beets among them were stripped of their leaves. The beets on that part of the weedy strip that had been cleaned out earlier were not damaged. The worms were just moving to the beets surrounding the weedy patches, but a thorough application of Paris green applied according to the instructions given later killed them and no further damage was done.

Furrow Trap

Weedy ground bordering a beet field is very often as bad as weeds in the field. As soon as the worms have destroyed the weeds on which they hatch, hunger compels them to search for food. At such times they travel in armies, devouring whatever green thing comes in their way. A furrow plowed about the field and a small stream of water kept running in it will prevent the advancing worms from entering it. Newly cut alfalfa thoroughly sprayed with Paris green placed in the path of the oncoming army will destroy the worms by thousands.

Irrigation

In case both the moths and worms escape your observation and you are not aware that your crop is being damaged until a large portion of the leaves are eaten, the damage can sometimes be lessened by applying water to the crop, thus stimulating the growth of beets. This is especially true if the season is dry.

Poison

After the webworms have appeared in a field the only way to prevent loss is to kill them by spraying with some poison. Paris green seems best for this purpose. **Being prepared for quick action as soon as the proper time comes to begin the fight is extremely important. Have all your forces mustered, all equipment in working order and a good supply of Paris green on hand. When the time comes strike and strike hard, working as rapidly as possible.**

The most vulnerable period of the webworm's life is during the first few days after it leaves the egg. There are two reasons why this is the best time to fight this enemy of the beet crop:

(1) If killed when young the worms will not have time to do much damage, **which means that they will not eat as much leaf before dying as they would if they were older.**

(2) It requires less poison to kill the young worms.

However, do not think that because less poison is needed to kill the young worms that less should be used, for this is not the case. Too diluted a poison will mean an unnecessary consumption of leaves to bring about the death of the worms.

Paris green gives more satisfactory results and works more quickly than any poison yet used for killing sugar beet webworms.

In using this poison apply not less than 4 pounds per acre. (For the method of determining the amount of poison applied per acre, see "Test Your Sprayer" on page 35).

A good type of traction sprayer, when properly adjusted, should apply about 50 gallons of water to the acre. If too little water is used the beet plants are apt to be burned; if too much is used much poison is wasted.

Arsenate of lead acts very much more slowly than Paris green, therefore seldom gives satisfactory results. This poison can be secured in two forms, dry and as a paste containing 50% water. These are not recommended except in case Paris green cannot be secured. **When used, not less than 8 pounds of the dry or 16 pounds of the paste should be applied per acre.** If the worms are large, arsenate of lead is **not** recommended, as it acts too slowly.

Best results are only secured when the poison is applied with a pressure sprayer which will maintain a pressure of 80 pounds. Such a machine produces the fine mist-like spray which is necessary in order to place the poison on the under side of the leaves.

Fig. 12. Result of Spraying—Left, Unsprayed; Right, Sprayed

The effect of spraying at the proper time, with the proper equipment and with the proper amount of Paris green, is clearly shown in Figure 12, Page 73. The left of the cut shows the unsprayed portion of the field and the right the sprayed portion.

See caution regarding the handling of Paris green, given on page 37.

WHY GROWERS DO NOT SPRAY

Beet growers have innumerable excuses for not spraying, few of which will stand the test.

Cost Too High

The cost is one of the reasons most frequently given for not spraying. It costs not to exceed $3.00 an acre to apply Paris green with labor at $3.00 per day and Paris green at 50 cents per pound. One thorough spraying may save the grower $20.00 worth of beets. Even though a moderate amount of damage is done in spite of the spraying, a saving of one ton or $10.00 an acre can be made.

Spraying Interferes with Haying

Some growers will not spray because it is haying time when the worms appear. Two men and one team can handle at least 15 acres a day and should do 20 to 25 acres. If a grower has 25 acres he can spray it in one day and save one or two tons of beets per acre or $250.00 to $500.00 in a day by spending a day's time and $75.00 for labor and poison. This is not a bad interest on his investment.

Fear of Poisoning Stock

The fear of poisoning stock by feeding sprayed beet tops often keeps a grower from spraying. As sprayed beet tops have been fed for many years without killing stock, this excuse seems to have no foundation. The fact that only a portion of the leaves present when the spraying is done ever enter the feed lot, because they have died and fallen off, together with the fact that the poison is very easily washed off by showers, would seem to reduce the question of poisoning stock to the very remotest of possibilities—so remote in fact that it need not be considered at all.

Fear of Breaking Beet Leaves

The fear of breaking off some of the beet leaves with the spray machines and team often keeps growers from spraying. The presence of a very few worms in a field will reduce the leaf surface of a crop much more than all the leaves that will be broken off during the spraying. The fact that there is only a hole here and there in the leaves makes the damage appear slight, but it does not take many such holes to equal the area of a whole leaf, although the loss is not nearly so apparent as when the whole leaf is broken off.

Hard to Realize Danger

It is often very hard for growers to realize that there is going to be any damage. The worms are small and inconspicuous, which makes their numbers appear insignificant as compared with the foliage of the beets. If in doubt yourself and the Sugar Company representative advises spraying, remember that this man has no interest in your spending more money on your crop unless by so doing you can produce a better crop.

DESCRIPTION

The Egg

The eggs of the sugar beet webworm moth (Fig. 5, Plate V, Page 19) are about the size of a small pin-head, of a pearly white color when first laid, becoming yellowish as the young worm develops within. When deposited singly they appear as shown at "A" of the figure. They often

occur in groups of from two to five or six or even more, when they are placed in rows, the eggs overlapping as shown at "B" and "C."

The Worm

Figure 3, "A," Plate V, Page 19 shows a young webworm, natural size, on a beet leaf. Figure 4, Plate V, Page 19 shows this same worm much enlarged. As they grow larger these worms become darker, appearing more like the full grown worms.

The full grown worm is shown enlarged in Figure 6, Plate V, Page 19. They are not very variable in color, although some individuals are somewhat lighter than the figure. The most characteristic marking is the dark line in the center of the back with the row of dark circles on either side, each with a small bristle in the center. These circles are grouped in pairs. When disturbed the worms jerk their bodies violently from side to side, often throwing themselves from the leaf.

The Pupa and Cocoon

The cocoon (Fig. 8, Plate V, Page 19) is composed of silk which is produced by the worm. These silken tubes, which are often 1½ to 2 inches long, reach to the surface of the soil. When removed with the earth adhering to them they appear like small earthen rods. The light portion of the figure shows where the soil has been scraped away, revealing the cocoon beneath.

The pupa (Fig. 9, Plate V, Page 19) is very active. When disturbed it will twist and squirm about in very much the same manner as the worm. At the tip are eight curved spines, four on either side, as shown in Figure 10, Plate V, Page 19.

The Moth

The moth (shown natural size, Fig. 11, Plate V, Page 19), with its delicate shades of gray, brown and tan, harmonizes so well with the colors of the soil that when resting on the ground it is hard to distinguish from its surroundings. When at rest its wings are folded over the body so that the moth is triangular in form like the outline drawing to the left of Figure 4, Plate VI, Page 21. When disturbed the moths fly up, making short, jerky, zigzagging flights.

LIFE HISTORY

The first webworm moths appear during the latter part of April and early May. About the first of June the moths of this first brood of the season are most numerous.

After mating takes place each female deposits several hundred eggs on sugar beets or on lamb's-quarters, Russian thistle, alfalfa and other plants growing in the field and along the ditch banks and fence rows.

At the end of from three to five days hundreds of hungry little worms hatch and begin their work of destruction.

Feeding continues from two to three weeks, the amount eaten daily increasing very rapidly until the worms are full grown. During the last two or three days before they enter the soil to pupate, the amount eaten is appalling.

When full grown the worms burrow into the soil and by much wriggling and twisting about form a long cell extending from the surface to a depth of 1½ to 2 inches. When the cell is completed the worm proceeds to line it with silk, which it spins into a tough, leathery cocoon.

After the cocoon is completed the worm begins to shorten and becomes very much wrinkled. All this time the pupal case has been forming just under the worm's skin, which breaks and the pupa wriggles its way out.

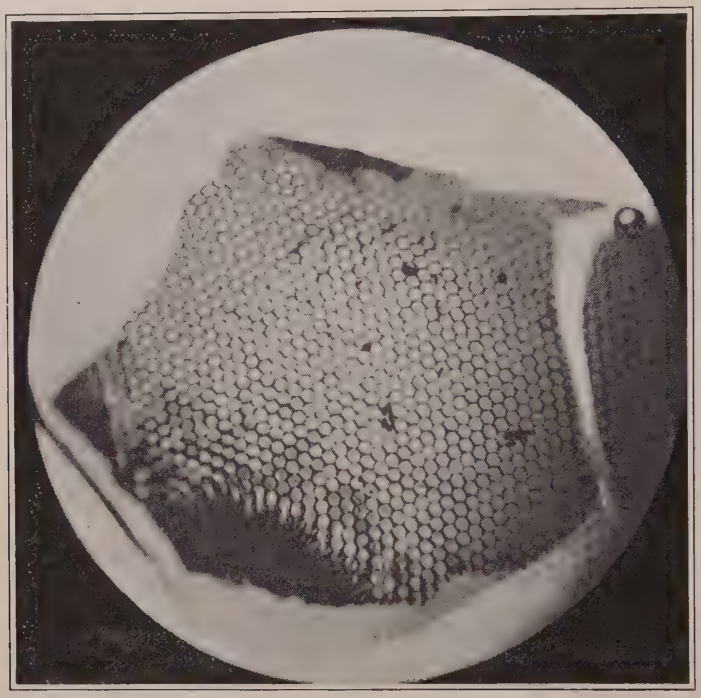

Fig. 13. A Portion of the Compound Eye of a Tiger-beetle, highly magnified. (See page 131)

While in the pupal stage legs, wings, antennae and a long proboscis with which the moth will suck the nectar from the alfalfa and other flowers upon which it feeds, two compound eyes, each composed of many smaller ones (See Fig. 13), and a covering of feather-like scales, are formed. After all this is completed the moth comes forth.

These moths from the first brood of worms mate and the females lay the eggs for the next brood. These worms pass through the same changes as the first until they enter the soil. All make cells like those of the first brood worms and line them with silk. Only a small portion of them pupate in the fall, however. The greater number remain unchanged in their cells until the following spring. With the coming of warm weather they change to the pupa and after ten days or two weeks, to moths, which are the first moths to appear in the spring.

The worms which pupate in the fall become moths in about ten or twelve days. After breaking out of the silken cocoons these moths mate and the females lay eggs for a third brood. When full grown, the worms of this brood enter the ground, where they remain in their cocoons, as worms, until spring.

How wisely Nature has provided for the carrying of the beet webworm over the winter! For fear that an early winter overtake the last brood in the fall and they perish, a part of the second brood is set aside as a sort of sinking fund against such a calamity. There is a considerable overlapping of the broods, so that the eggs and several sizes of worms may be present at one time.

NATURAL ENEMIES

Ichneumon-flies

The dusky winged parasite [9] (Fig. 7, Plate V, Page 19) is one of the most common enemies of the sugar beet webworm. The larva of this parasite develops within the webworm, but does not kill it until after it has entered the ground and spun its cocoon. Then instead of the moth, the parasite emerges from the cocoon.

This parasite has four dusky wings. Near the center of each of the forward pair is a partially clear area. The body is dark reddish or bay and the legs have dark bands which give them the appearance of being ringed.

Braconids

The little wasp-like parasite [3] (Fig. 14, Plate V, Page 19), which is a Braconid, frequently emerges from a cocoon instead of the webworm moth.

Tachina-flies

The Tachina-fly [16] (Fig. 13, Plate V, Page 19) fastens its eggs onto the webworm and when the maggots hatch they burrow into it. At first the webworm appears to be little disturbed by the maggots, but as the latter increase in size their feeding weakens the worm, which finally dies. When fully grown, the maggots change to pupae inside the puparium (Fig. 12, Plate V, Page 19). The adult fly breaks open the end of the puparium, as shown in the figure, and escapes.

Solitary Wasp

One of the enemies of the sugar beet webworm belongs to a group of wasps known as solitary wasps. (See page 135.)

This wasp [13] (Fig. 15, Plate VI, Page 21) places its eggs in tunnels, one of which is shown in cross section in Figure 14, Page 78. These tunnels are dug in the soil about the borders of fields.

The mouth of the tunnel is always built up a half inch or so above the surface of the soil. When the nest is completed several webworms are caught and after being stung, which paralyzes them, they are placed at the bottom of the tunnel. After a single egg is deposited among the worms a wall is built so as to make a small cell at the lower end of the tunnel. The chimney-like mouth is next filled with mud. The larva which hatches from the egg feeds upon the webworms until ready to change to the pupa. This change takes place in the burrow, from which the adult wasp escapes by digging its way out.

(3-9-13-16) See explanation of "Reference Figures," page 2

Fig. 14. Cross Section through Burrow of the Solitary Wasp

Robber-flies

There is a family of flies commonly known as robber-flies (Fig. 12, Plate VI, Page 21), the members of which prey upon other flies, as well as upon bees and their near relatives, small flying beetles and moths. These flies will often be noticed resting on the ground or some object which furnishes a clear view of the surroundings, patiently waiting for some victim to appear. Their heads are joined to the body by a freely moving neck so that they can be moved at will. While waiting for some ill-fated fly to appear the head is moved about following the flight of passing insects in really human fashion.

These flies capture their victims by pouncing upon them in true bird of prey fashion. Holding the victim with their long legs, the beak is thrust into its body and the contents sucked up. One of these flies was observed to capture and feed upon a webworm moth.

(b) TRUE ARMY WORM

(Figs. 21, 22, 24 and 25, Plate I, Page 11)

The true army worm is one of those insects which, while always present in small numbers in our fields, commonly escapes, unobserved, because of its seclusive habits. However, when for any reason the natural checks become abnormally scarce or favorable weather conditions prevail in connection with a plentiful food supply, it multiplies very rapidly, overrunning our fields in vast hordes, often traveling in such large numbers that the very earth seems to move. All follow the same general direction, destroying crops as they go, and leaving nothing but the riddled remains of what a few days before gave promise of a bountiful harvest.

NATURE OF INJURY

In the case of leaf-eating insects the damage done is usually proportionate to the amount of leaf surface destroyed. However, the true army worm is an exception to this rule. When feeding, these worms have the habit of climbing grass and grain stalks and gnawing off the heads. When grain is in the shock, especially if harvested a little green, the heads are often gnawed off also. For this reason the damage greatly exceeds that of most insects of this class in that the army worm destroys much more than it actually eats.

Sugar beets are seldom damaged except where they lie in the path of the moving worms or next to infested small grain or grass crops. When attacking this crop the worms overrun the leaves, at the same time eating irregular areas out of their margins. In case of severe injury all of the leaves with the exception of the coarse stems may be destroyed. The roots are seldom, if ever, eaten. The army worm usually appears so late in the season that few beets are killed.

METHODS OF CONTROL

Spraying

When the nature of the crop attacked is such that poison can be applied in the form of a spray, without danger of poisoning either live stock or human beings that use the crop as a food, the army worm can be effectively controlled by spraying with Paris green or lead arsenate. The same proportions of poison and water should be used as in the control of the beet webworm; i. e., 4 pounds of Paris green or 16 pounds of arsenate of lead paste to the amount of water used in spraying an acre. Remember that the sprayer should be adjusted so as not to apply more than 100 to 125 gallons per acre.

Poisoned Bait

When the food supply has become exhausted and the worms have started across country in search of new pasturage, the poisoned bait recommended in the control of cutworms will prove most effective. (See pages 39 and 40.) This should be scattered in the path of the worms. Several strips of a rod or so wide with about the same distance between them will give the best results. As the worms are most active during the latter part of the afternoon this is the best time to put out the bait; however, if the army is on the move earlier, the poison should be scattered earlier.

Furrow Trap

This consists of a furrow plowed across the path of the advancing worms. The soil should be thrown toward the worms so as to leave the perpendicular side of the furrow opposite them. Post holes should be bored in the bottom of the furrow every few feet. As the worms enter the furrow they will attempt to climb up the perpendicular side. Many failing in this will wander up and down the furrow in search of a place where they can climb out. In this way many will fall into the post holes. The worms thus trapped can be killed by crushing them with a piece of wood or by pouring a small quantity of kerosene into each hole. Sometimes the post holes are not used. In their stead a small log or heavy

post is hauled up and down the furrow to crush the worms. The furrow in connection with the poisoned bait makes a very effective combination.

DESCRIPTION

The Egg

The eggs have a smooth shining surface. When first laid they are of a pearly white. As the young worm develops the color changes to a creamy flesh color, gradually becoming darker until just before the young worm emerges, when it is a dull gray.

The moths appear to prefer the dense growth of grass or grain which commonly grows on old stack bottoms or about manure piles or the droppings of animals in pastures, as places to deposit their eggs. Injury to small grain is often first observed where this heavy growth occurs on old stacking grounds.

The eggs often occur in clusters of a hundred or more. Usually they are deposited in the sheath of grass and grain leaves, sometimes between two leaves which happen to be fastened together. Egg laying takes place during the night. A single female moth has been known to lay 254 eggs, and as many as 800 developed and undeveloped eggs have been taken from the abdomen of one moth.*

The Worm

In from eight to ten days after the eggs are laid, the young worms appear. As they emerge from the egg they are whitish with brown heads. The first act of the newly hatched worm is to eat the shell of the egg from which it has just escaped.

During the course of their development the worms shed their skins several times. As soon as the worm has cast off its old coat it proceeds to devour it as if attempting to cover up its trail.

The full grown worms (Figs. 21 and 22, Plate I, Page 11) are variable in color, some being considerably lighter than the figures. The figures are so lifelike that a description of the coloring is not necessary. When disturbed the worms curl up as shown in Figure 21. This is not characteristic of the army worms alone, however, as many caterpillars, especially cutworms, have the same habit. When fully grown the army worms enter the soil, where they form a cell in the same way as the cutworms. In this cell the worm spins a thin, silken cocoon within which it changes to the pupa.

The Pupa

The pupa (Fig. 24, Plate I, Page 11) of the army worm does not differ greatly from that of the cutworms already mentioned. At first it is a light creamy yellow. When fully colored it is of a rich mahogany brown. At the tip there are four spine-like appendages as shown in the figure. After spending from two to three weeks in the pupal stage the moths appear.

The Moth

The moth (Fig. 25, Plate I, Page 11) is a night flyer and is seldom seen on the wing during the day unless the weather is cloudy and damp.

*Davis and Satterthwait, "Life History Studies of *Cirphis unipuncta*, the True Army Worm," Journal of Agricultural Research, Vol. VI, No. 21 (1916).

The most characteristic marking is the white spot near the center of each fore wing. The last part of the army worm's Latin name, "*unipuncta*," is derived from this spot and means one point.

LIFE HISTORY

So far as known, the army worm passes the winter, in the northern half of the United States, as a partially grown worm or larva. The first moths appear during May or June, depending upon the season and the locality. The cooler the season and the farther north we go the later they appear.

The eggs are laid soon after the moths emerge, and the young worms appear during June. These feed for about three weeks and then change to pupae, in which form they remain from eight to eleven or twelve days, when the adult moths come forth.

The second brood is in the egg stage about the middle of July, in the worm stage during the latter part of July and early August, in the pupal stage during the latter part of August, and the moths issue between the the last of August and the 8th or 10th of September.

The third brood of worms hatches during the latter part of September and early October. These worms spend the winter as partially grown larvae and complete their development the next April.

In the southern part of the country a fourth generation may occur.

NATURAL ENEMIES

Parasitic Flies

Several species of parasitic flies destroy the army worm. Two species, "*Archytus apicifere* Walk" and a "*Winthemia*"* species (near *militaris* Walsh) have been bred from parasitized army worms taken in Boulder County, Colorado.

Birds

Birds, especially blackbirds, meadow larks and other ground feeding species, render valuable service in destroying these worms.

Ground Beetles

Ground beetles and their larvae also devour large numbers of army worms.

(c) ALFALFA LOOPER

(Figs. 5, 6, 7 and 8, Plate VI, Page 21)

The first authentic record of this insect as a crop pest** states that during June, 1895, considerable damage was done to alfalfa near Grand Junction, Colorado, by the caterpillars. Again in 1914 reports of injury by this insect came from the same locality. The same year the looper also appeared in large numbers in the Yellowstone Valley in Montana and in adjoining territories, where considerable damage was done to both alfalfa and sugar beets. The latter were damaged only in those instances where the worms migrated from alfalfa fields or the sweet clover growing on waste land.

*Determined by C. H. T. Townsend.

**J. A. Hyslop, "The Alfalfa Looper," Bulletin No. 95, Part VII, Bureau of Entomology, U. S. Department of Agriculture (1912).

NATURE OF INJURY

The injury to sugar beets is similar to that caused by other leaf-eating caterpillars. The destruction of the leaves reduces the yield and sugar content of the crop.

Both the leaves and blossoms of alfalfa are eaten. This reduces the yield and quality of hay. The destruction of the blossoms reduces the yield of seed where the crop is grown for seed production.

METHODS OF CONTROL

As this insect seldom if ever attacks sugar beets until its favorite food plants (alfalfa and sweet clover) are exhausted, such attacks can be anticipated and preventive measures employed to protect the crop.

Furrow Trap

In case sugar beets adjoin infested alfalfa or waste land overgrown with sweet clover the furrow trap recommended for the control of the true army worm (page 79) can be used with good results. The furrow should be thrown away from the beets so as to leave the perpendicular side next to them. If water is available a small stream in the furrow will add to its effectiveness.

Poisons

Where the loopers are feeding on alfalfa or sweet clover growing on ditch banks or fence rows about beet fields these plants should be sprayed with Paris green or arsenate of lead, using 2 to 3 pounds of the former or 8 to 12 pounds of the latter if the paste is used, or 4 to 6 pounds of the dry form, to 50 gallons of water.

If the caterpillars have entered a beet field, spray the beets, using the proportions of poison and water given above.

Bunches of freshly cut green alfalfa or sweet clover, sprayed with Paris green and placed in the furrow, where the furrow trap is used, will kill many of the loopers.

Mowing

Where alfalfa is being damaged it should be mowed at once. The longer it stands the poorer the quality will be. After the hay is removed the stubble should be sprayed to destroy the worms and protect the new growth.

If strips of alfalfa are left uncut at intervals through the field the loopers will congregate on these and can then be killed by spraying the standing alfalfa. When the worms have been destroyed the alfalfa on the strips can be removed. **This hay should not be fed unless heavy rains have washed off the poison.**

Close watch should be kept of the worms after the infested hay is cut to prevent their migrating to adjoining crops.

DESCRIPTION

The Egg

The eggs are pale yellow, hemispherical in shape, rounded at the base, the apex with a rounded depression, and are finely creased vertically.*

*J. A. Hyslop, "The Alfalfa Looper," Bulletin No. 95, Part VII, Bureau of Entomology, U. S. Department of Agriculture (1912).

The eggs are deposited on the food plants. Moths have been observed in the act of laying at three o'clock in the afternoon.*

The Caterpillar

These caterpillars differ from all others discussed in this Bulletin in having but three prolegs on each side of the posterior half of the body. By comparing Figure 1 and Figure 5, Plate VI, Page 21, this difference is made more apparent. It will be noticed that Figure 1 has four legs just back of the center, and one at the tip of the body, and that Figure 5, which represents a full grown alfalfa looper, has but three including the one at the tip.

The alfalfa loopers vary greatly in color.

The darker parts of different individuals range from a dark olive brown to pale greenish brown. The figure represents one of the lighter type.

The Cocoon

The cocoon (Fig. 6, Plate VI, Page 21) is made of several leaves of the host plant held together by loosely woven silk threads. Sometimes the cocoons are constructed among dead leaves and trash on the ground.

The Pupa

After the worm has completed its cocoon it changes to the pupa within it. The pupa (Fig. 7, Plate VI, Page 21) is very similar to those of the cutworms and army worms.

The Moth

The adult (Fig. 8, Plate VI, Page 21) is one of our most beautiful moths. The figure is so true to life that no description is necessary. The silvery spot near the center of the fore wing is characteristic of this and related moths.

LIFE HISTORY

This insect probably passes the winter in hibernation in the pupal stage. During the latter part of May and early June the eggs for the first brood of worms of the season are laid.

The length of the egg stage is not definitely known. The worms feed for about two weeks, at the end of which time the cocoon is made and the change to the pupal stage takes place. This lasts about ten to twenty days during ordinary summer weather.

The first adults of the second brood appear during late June and early July. There are two and possibly three generations each season.

NATURAL ENEMIES

The alfalfa looper appears to be a favorite host of many parasites. The Ichneumon-fly [8], shown in Figures 9 and 10, Plate VI, Page 21, was reared from alfalfa loopers taken at Edgar, Montana, and several other species have been reared from alfalfa loopers by Mr. Hyslop.

Many of the caterpillars succumb to a bacterial disease. The infected worms become dark in color soon after dying. The dead worms

*Mr. Koebels, Bureau of Entomology Notes, No. 95-K.

(8) See explanation of "Reference Figures," page 2.

hang limp from the host plant at first, but finally the body becomes so decayed that it drops to the ground.

(d) ALFALFA WEBWORM*

(Figs. 1, 2, 3 and 4, Plate VI, Page 21)

During the summer of 1914 the alfalfa webworm [1] appeared in large numbers in Northern Colorado, where it did considerable damage to first cutting alfalfa. While they appear to prefer this crop and sweet clover, the worms caused some anxiety among sugar beet growers by feeding upon the leaves of sugar beets.

NATURE OF INJURY

When attacking alfalfa the worms spin masses of whitish web at the tips of the plants, inclosing the new, tender leaves and blossoms. This web furnishes protection for the worms while they feed upon the inclosed parts.

Injury to sugar beets is similar to that caused by the sugar beet webworm. Some of the leaves will be found partially covered by a web which terminates in a long tube extending to the ground, the lower end being among the clods on the surface. When but few worms are present there is usually only one to a plant.

METHODS OF CONTROL

Poison

This worm can be controlled on sugar beets by spraying with any arsenical poison. The same amounts of poison should be used as for the control of the sugar beet webworm (pages 72 and 73), and should be applied in the same way.

Mowing

In case alfalfa is being damaged it should be cut at once, cured and put up to prevent loss. After removing the crop the stubble can be sprayed. (See "Mowing," page 82.)

Irrigation

Irrigating after the worms have entered the ground to pupate will seal them in, preventing many moths from emerging when mature.

DESCRIPTION

The Worm

Although closely related to the sugar beet webworm, this worm (Fig. 1, Plate VI, Page 21) is easily distinguished from it by its coloring. The central portion of the back is occupied by a light stripe tinged with flesh color. On either side of this there is a dark stripe about the same width. Along the upper and lower margins of these dark stripes there are several dark circular spots, each bearing a hair-like bristle. With the exception of those segments next to the head and at the tip of the body, each segment has three of these spots, two on the upper border of

*This is a local name applied to this insect in Northern Colorado. This insect should not be confused with "*Loxostege similaris* Guen." which is also called the alfalfa webworm. (See Bulletin 109, Oklahoma Agricultural Experiment Station, February, 1916).

(1) See explanation of "Reference Figures," page 2.

the dark stripe and one on the lower. Just below the dark stripe is another light, more or less flesh-colored one, and below this the body is dusky, but not so dark as the other dark portions. There are several dark circles within the dusky portion, each bearing a bristle. The lateral portions of the first segment back of the head are dark. The head is mottled with dark brown on a lighter ground color.

The worms are very active. If their webbed retreats on alfalfa are disturbed they throw themselves to the ground or run rapidly down the stems.

When on sugar beets they will be found concealed at the end of the long, silken tube already mentioned, among the clods near the crown of the plant. If the soil is disturbed the worms run rapidly to the web among the leaves, and if disturbed here they descend to the end of the tube again just as rapidly. They appear to travel backward as freely as forward.

The Pupa

When fully grown the worms enter the soil and spin a cocoon very similar to that of the sugar beet webworm, but more loosely made, in which they change to the pupa (Fig. 2, Plate VI, Page 21). The pupa is very much like that of the beet webworm, but can be readily distinguished from it by the eight spatulate (spoon-shaped) appendages at the tip (Fig. 3, Plate VI, Page 21), those of the sugar beet webworm being curved and pointed.

The Moth

In warm weather the moths appear in about six or eight days after the worms change to pupae. By comparing the figure of this moth (Fig. 4, Plate VI, Page 21) with that of the sugar beet webworm (Fig. 11, Plate V, Page 19), the differences are clearly brought out. It will be noticed that the under wings of the alfalfa webworm are much darker than those of the sugar beet webworm moth and that the markings of the upper or fore wings are darker as well as different in form. Flying in the field the two are very hard to distinguish from each other.

LIFE HISTORY

So far as known to the writer, there are no published accounts of the life history of this insect. In general it is probably quite similar to that of the sugar beet webworm. The injury to alfalfa referred to above occurred during the last of June. The moths of this brood appeared July 14th. During August another brood of worms appeared. This second brood was not so numerous and did less damage than the first. In all probability, in the latitude of Denver, the winter is passed in the larval or pupal stage.

NATURAL ENEMIES

An undescribed Tachina-fly, [15] (Fig. 11, Plate VI, Page 21), was reared from caged worms.

Birds and poultry no doubt do much to hold this insect in check.

(15) See explanation of "Reference Figures," page 2.

(e) YELLOW-BEAR CATERPILLAR

(Figs. 15 and 16, Plate V, Page 19)

The yellow-bear caterpillar is always in evidence, in small numbers, on Russian thistle, lamb's-quarters and other weeds along the fence rows, ditch banks and roadsides. As a rule they are not numerous enough to cause noticeable damage to crops. Occasionally, however, they become so numerous that the wild food plants are not sufficient for their support. At such times the caterpillars attack whatever growing crop happens to be nearest at hand. Such an outbreak occurred during August and September, 1909, in the Arkansas Valley in Southern Colorado.*

NATURE OF INJURY

When young the worms eat only the surface of the leaves but as they become older and larger the margins of the leaves are eaten away and holes are eaten into them. When very numerous, crops are completely defoliated by these caterpillars, or in the case of sugar beets the stems, midribs and young heart leaves only are left untouched. Severe attacks on sugar beets result in a lowering of the yield and sugar content of the crop.

The yellow-bear is one of the most general feeders among the whole list of crop pests. The following list of plants injured is given by Mr. Marsh in the bulletin already referred to:

Sugar beet	Radish	Squash
Stock beet	Celery	Watermelon
Table beet	Carrot	Cantaloupe
Rhubarb	Parsnip	Sweet potato
Cabbage	Egg plant	Corn
Cauliflower	Potato	Lima bean
Turnip	Pumpkin	String bean
Asparagus	Dahlia	Amaranthus
Pea	Cherry	Chenopodium
Peanut	Gooseberry	Helianthus
Alfalfa	Blackberry	Solanum rostratum
Hollyhock	Raspberry	Verbesina
Morning-glory	Currant	Ambrosia
Canna	Grape	Russian thistle
Hyacinth	Dock (Rumex)	Spanish needle

METHODS OF CONTROL

Poison

In his work in the Arkansas Valley of Colorado, Mr. Marsh experimented with both Paris green and arsenate of lead. It was found that arsenate of lead, even where applied in quantities as high as 8 pounds to 100 gallons of water, was of little value in the control of the yellow-bear caterpillar. Paris green used at the rate of 10 pounds to 100 gallons of water to which 10 pounds of lime was added to prevent injuring the leaves killed practically all caterpillars in three days.

From the results of this work it appears that this worm is very resistant to arsenical poisoning, the ordinary amounts being practically valueless in its control.

*H. O. Marsh, "Biologic and Economic Notes on the Yellow-bear Caterpillar," Bulletin No. 82, Part V, Bureau of Entomology, U. S. Department of Agriculture (1910).

DESCRIPTION

The Egg

The eggs are laid in clusters on some green plant. In the Arkansas Valley Mr. Marsh found large numbers of eggs on rhubarb, which appears to be a favorite food plant.

The Caterpillar

Unlike the cutworms and the other caterpillars so far considered in this Bulletin, the yellow-bear is completely covered with a coat of tawny hair. This varies from a reddish brown in the darker individuals to a light yellow or straw color in the lighter ones. Figure 15, Plate V, Page 19 represents one of the lighter type. The body of the caterpillar is most often pale yellow or straw color with a darker stripe running lengthwise on either side.

The Pupa

The pupa is more robust than that of the cutworms already mentioned. Instead of entering the ground to pupate the worms seek some secluded place such as underneath boards and other objects lying on the ground or among the dead leaves and trash about the borders of fields and on ditch banks. Here the caterpillar forms a loose cocoon composed almost entirely of its own hairs held together by threads of silk, within which it changes to the pupa and later to the moth.

The Moth

The adult yellow-bear (Fig. 16, Plate V, Page 19), sometimes known as the Virginian tiger-moth, is one of our most delicate night fliers. Pure white with dark spots on the wings and three rows of black dots on the body alternating with two yellow stripes, this moth presents a striking contrast to the dusky winged cutworm moths.

LIFE HISTORY

This moth spends the winter in the pupal stage concealed under trash along fence rows and ditch banks and on other waste ground. The moths appear in early summer to deposit the eggs for the first brood of worms, which become mature about the last of July. The second brood appears during August and becomes fully grown about the first week of September. These worms pupate after spinning the loose cocoon already mentioned and remain in this form until the next spring.

NATURAL ENEMIES

The natural enemies of the yellow-bear appear to be peculiarly few. Because of their covering of hair few birds feed upon them. Certain Tachina-flies destroy a few worms and in some localities many die of a fungous disease.*

(f) ZEBRA CATERPILLAR

(Fig. 11, Plate III, Page 15)

This is one of our most striking caterpillars. When resting on a beet with its bright colors contrasted with the dark green of the leaves it is almost a thing of beauty.

**Botrytis bassiana* Bals.

NATURE OF INJURY

The zebra caterpillar bears the distinction of being the first insect reported as damaging beets in the United States.* While it seems to prefer vegetable crops, especially beets, and cabbage, turnips, and other cruciferous plants in general, yet it feeds upon field crops and even the leaves of trees and shrubs.

METHODS OF CONTROL

Dr. Chittenden* states that this insect yields readily to sprays of arsenicals. Paris green or arsenate of lead, the former at the rate of 2 to 3 pounds and the latter at 4 to 6 pounds dry or 8 to 12 pounds of the paste, to each 100 gallons of water, will give satisfactory results.

DESCRIPTION

The Egg

The eggs are deposited in clusters of from several to as many as a hundred or more, usually on the under side of the leaves of the food plants.

The Caterpillar

At first the worms are whitish in color with dark heads and several dark spots scattered over the body. While small they feed in compact groups, but after several days the skin is shed and the caterpillars take on the colors of the adult worm (Fig. 11, Plate III, Page 15) and gradually become scattered. When disturbed the worms coil up and fall to the ground.

The Moth

The moth is about the size of the adult western army cutworm (Fig. 3, Plate I, Page 11). The fore wings are a chestnut brown shaded with purplish brown. The hind wings are whitish with pale brown margins.

LIFE HISTORY

The zebra caterpillar passes the winter in the pupal stage in the ground. The first moths appear in May and June. In moderate temperatures the eggs hatch in about six days. The worms feed four or five weeks and then change to pupae, in which form they remain for about sixty days. The moths of the second brood appear in late August or September. The second brood of worms feeds during the fall, the change from worm to pupa taking place before winter sets in.

NATURAL ENEMIES

This caterpillar appears to be especially attractive to the various parasitic insects infesting caterpillars in general. Many are killed by fungous diseases, while birds no doubt destroy them in large numbers.

2. LEAF-EATING BEETLES

There is a family of variously colored beetles of small or moderate size, the members of which are called "leaf-beetles" because they feed upon the leaves of plants in both the adult and larval stages, with a few

*Dr. F. H. Chittenden, "A Brief Account of the Principal Insect Enemies of the Sugar Beet," Bulletin No. 43, Division of Entomology, U. S. Department of Agriculture (1903).

exceptions where the larvae are root feeders. The Colorado potato-beetle is the best known representative of this family.

Several leaf-beetles feed upon sugar beets and under certain conditions do considerable damage to the crop. The principal species of this family, together with other leaf-eating beetles attacking sugar beets in the Great Plains area, are discussed in the following pages.

(a) LARGER SUGAR BEET LEAF-BEETLE OR ALKALI-BEETLE

(Figs. 1 to 5, Plate VII, Page 23)

In Northern Colorado this beetle is known as the "alkali-beetle" or "alkali-bug", from the fact that it breeds most freely on the weeds growing on low, damp ground where the alkali is brought to the surface by seepage. In some other parts of its range it is known as the "French bug".

NATURE OF INJURY

Both the larvae and the adults damage sugar beets. Injury usually occurs on the border of fields next to waste land which is damp and contains an excessive amount of alkali. The adults are very active on the wing and often appear in swarms in the center of fields or at considerable distances from low wet ground. When few in number their work appears very similar to that of the flea-beetles only that the holes in the leaves are larger. (See Fig. 1, Plate IV, Page 17). In severe cases nothing but a network composed of the larger veins of the leaves is left and the leaf becomes brown and shriveled.

METHODS OF CONTROL

Spraying or Burning Weeds

When beets are planted near low, damp ground the weeds on this waste land should be watched closely in early summer. If alkali-beetles and their larvae appear in numbers the weeds should be sprayed with Paris green or straw should be scattered among them and burned.

The destruction of the beetles and larvae at this time will prevent their migrating into the beet fields and will also reduce the number of eggs laid later.

Spraying Crop

In case the beetles and larvae have already begun to damage beets, Paris green should be applied as a spray, using 4 pounds to 100 gallons of water. Many times it happens that only a small portion of the field is being damaged, making it inconvenient to use a team and power sprayer. In such case a knapsack sprayer (See page 36) can be used to advantage.

Paris Green Applied Dry

Good results have followed a dry application of Paris green. If to be applied in this way mix at the rate of 1 pound of the poison to 10 pounds of low grade flour or finely pulverized air-slaked lime. This mixture can be dusted over the beets by using a sack made of coarse cloth or a tin shaker with the bottom perforated with rather small holes. Best results are secured if the dusting is done early in the morning when the

dew is still on the beets. Never attempt to apply the dry poison when the wind is blowing. Always spray or dust the beets some distance beyond where the insects are feeding.

DESCRIPTION

The Egg

The brownish gray eggs (Fig. 3 enlarged and Fig. 4 about natural size, Plate VII, Page 23) are usually placed in clusters on the under side of the leaves of the food plants. Russian thistle and saltbush, both of which abound on alkali ground, are favorite plants on which to deposit the eggs.

The Larva

The young alkali-bug is sluggish in its movements. In color it is a dirty gray at first, becoming darker with age. When fully grown it appears as in Figure 1, Plate VII, Page 23. At this time the ground color is an olive brown. The entire body is covered with blunt tubercles each bearing several short, stiff hairs. These tubercles are yellowish in color, giving the larva a spotted appearance.

The Pupa

The pupa (Fig. 2, Plate VII, Page 23) is what is known as a "free pupa" because the legs and other parts of the insect are encased separately, in contrast with the pupae of the cutworms and other related insects. The pupal stage is passed in a small oval cell in the soil. At first the pupa is a uniform yellowish brown as shown in the figure, but just before the adult emerges the color becomes darker.

The Beetle

The adult alkali-beetle (Fig. 5, Plate VII, Page 23) often occurs in swarms. In color it varies from a light brownish yellow to almost black. Sometimes the wing covers are quite distinctly striped, the dark color being concentrated near the center of each. The figure represents an intermediate color type.

(b) WESTERN BEET LEAF-BEETLE

(Fig. 6, Plate VII, Page 23)

As the name indicates, this beetle is a Western insect. It is more common on the Pacific coast than in the Rocky Mountain regions. It first attracted attention in the years 1900 and 1901 in Oregon.*

This beetle (Fig. 6, Plate VII, Page 23) is very similar to the "larger sugar beet leaf-beetle" in coloring but is only slightly more than one-half as large. Its habits appear to be similar to those of the preceding species.

NATURE OF INJURY

The only cases known to the writer where this beetle has injured sugar beets have been near low, damp ground, the beetles alone damaging the crop. The early stages have not been observed by the writer.

*Dr. F. H. Chittenden, "A Brief Account of the Principal Insect Enemies of the Sugar Beet," Bulletin No. 43, Division of Entomology, U. S. Department of Agriculture (1903).

METHODS OF CONTROL

The same control measures employed against the preceding species should be used in case this insect attacks sugar beets in sufficient numbers to damage the crop.

(c) FLEA-BEETLES

The individuals of one group of leaf-beetles are characterized by having the joint of the hind legs next to the body much enlarged. This enables them to jump long distances. The habit these beetles have of making sudden leaps whenever disturbed suggested the popular name "flea-beetle" which is applied to the members of this group.

Most flea-beetles are small, but some species are of moderate size. The color is variable, some species being dull black or brown; others are shining black, often with a metallic sheen; some are deep shining blue; while in others parts of the insect are red or yellow or striped.

These active little insects are familiar objects to every person engaged in either gardening or farming, appearing in swarms on crops during spring and early summer. Several species attack sugar beets, often threatening serious damage.

NATURE OF INJURY

The work of flea-beetles is quite characteristic. The leaves of the plants attacked are eaten full of small holes popularly known as "shot holes" (Fig. 1, Plate IV, Page 17). The leaves of the seedling beets are sometimes completely destroyed. In severe cases the plants may be killed. Usually, however, plants which appear dead will put forth new leaves in the course of a week or ten days.

METHODS OF CONTROL

Destroy Weeds

Flea-beetles, in both the adult and larval stages, feed upon many of our common weeds. Clean culture, especially keeping down all weeds along fence rows and ditch banks, will effectively check the multiplication of this pest. Poverty-weed is a favorite food plant of the banded flea-beetle. (See page 92).

Spraying

Beets are usually attacked while still quite small. For this reason spraying is seldom advisable, since the plants will often be stripped of their leaves before the beetles have eaten enough poison to kill them.

Scattering

The beetles are easily disturbed and the swarms readily scattered either by the hand labor while thinning or by the cultivator in cultivating. In case the beetles appear in a field before the beets are thinned, it is always advisable to disperse them before this work is done. This can be accomplished by cultivating the field. If pieces of rope or strips of canvas are fastened to the frame of the cultivator so as to drag on the ground the insects will be more completely scattered.

Irrigation

The beetles dislike damp ground. Advantage can be taken of this fact, especially in dry years. If the beets are irrigated the insects will usually leave the field. The irrigation will stimulate the young beets so that they will outgrow the damage more quickly and completely. In case irrigation is resorted to great care should be exercised to prevent flooding the field as flooding young beets is injurious to them.

Poison

In cases where the use of poison is advisable Paris green mixed as recommended in the control of the alkali-bug (page 89) should be used. If the area to be treated is not too large, Paris green applied dry, mixed with ten parts of low grade flour, will give very satisfactory results, especially if the plants are small.

According to Dr. Chittenden,* Paris green mixed with Bordeaux mixture gives better results than the Paris green and water spray. As a rule spraying the upper surface is sufficient, but for some species attacking truck crops the under surface must also be sprayed.

(c-1) BANDED FLEA-BEETLE

(Fig. 2, Plate IV, Page 17)

About the time early beets are ready to block and thin, swarms of banded flea-beetles (Fig. 2, Plate IV, Page 17) often appear in the fields. Seldom is the whole field affected at one time, however. The beetles being very active, the same swarm may appear in several places in a field within a short time, thus causing considerable damage. Poverty-weed is a favorite food plant of this beetle. Damage to beets is most apt to occur in fields where this weed is growing.

DESCRIPTION

The Egg

Dr. Chittenden, in the bulletin already referred to,* states that the eggs are laid in June and July. They are about one-fourteenth of an inch long, elliptical in form and of a light buff-yellow color.

The Larva

The larva is a slender, whitish grub. The body is narrowest at the head, gradually widening toward the opposite end. The extreme tip of the body tapers abruptly, ending in a prolonged process which bears several stiff hairs. In this stage the flea-beetles feed upon the roots of some crops and weeds.

The Adult

The adult beetle (Fig. 2, Plate IV, Page 17) is slightly more than one-eighth of an inch in length. The color is somewhat variable. A characteristic marking is the yellow stripe on each wing cover. The figure represents one of the darker colored individuals.

*Dr. F. H. Chittenden, "A Brief Account of the Principal Insect Enemies of the Sugar Beet," Bulletin No. 43, Division of Entomology, U. S. Department of Agriculture (1903).

LIFE HISTORY

The life history of this beetle is imperfectly known. It is thought that the winter is passed in the larval stage only. The adults are most numerous in June and July, during which months mating and egg laying take place. There is no positive evidence of a second brood.

(c-2) POTATO FLEA-BEETLE

(Fig. 5, Plate IV, Page 17)

Not infrequently swarms of the potato flea-beetle appear in fields of sugar beets, causing considerable damage to small areas. At such times the injury to the crop is similar in every way to that caused by the striped flea-beetle and the same remedies should be applied.

This insect's liking for potatoes is indicated by its common name "potato flea-beetle," while its habit of attacking cucumbers and related plants suggested the second part of its scientific name, "cucumeris."

DESCRIPTION

The Larva

The larvae are small, whitish grubs which feed in the roots of several common wild plants all belonging to the same family as the potato. The roughened condition of potatoes known as "pimply" potatoes is caused by the larvae burrowing into the tubers.

The Adult

The adult beetles (Fig. 5, Plate IV, Page 17) are a dull black with the exception of the legs and antennae, which are yellowish. The wing covers are clothed with very fine hairs and their surface is covered with small punctures which are arranged in rows. The thorax has a deep, curved depression across the posterior margin, as shown in the figure. The small outline drawing at the left of the figure is the natural size of the adult.

LIFE HISTORY

The eggs are deposited on the roots of the host plants during May and June by the adult beetles, which have spent the winter in hibernation under dead leaves and other trash along ditch banks, fence rows and roadsides.

The larvae tunnel into the roots of the host plants, where they feed until fully grown. The mature larvae form small, oval cells in the soil, near the roots of the plants within which they fed, and change to pupae.

(c-3) THREE-SPOTTED FLEA-BEETLE

(Fig. 6, Plate IV, Page 17)

The three-spotted flea-beetle (Fig. 6, Plate IV, Page 17) is conspicuous in beet fields in early spring mainly because of its size and coloring. It is one of the largest flea-beetles and is readily distinguished by the yellowish-red thorax bearing three black spots.

Lamb's-quarters and related plants, such as Russian thistle and sugar beets, appear to be favorite food plants of this species.

Seldom, if ever, does this beetle occur in great enough numbers to require the application of remedial measures.

(d) SPINACH CARRION-BEETLE

(Figs. 10 and 11, Plate VII, Page 23)

The spinach carrion-beetle belongs to a family of insects the greater part of whose members feed upon decaying animal matter. These beetles are common objects under the carcasses of dead animals lying on the ground.

A few species of this family, however, feed upon vegetable matter, and some on fungi, while others, like the species under discussion and its near relative, the black carrion-beetle (Schwarze Aaskäfer) of Germany, feed upon sugar beets and other crops and upon field weeds.

From field observations it seems quite probable that the growing of sugar beets is not responsible for the presence of this pest in a neighborhood, but that its presence is due to some of its favorite host plants being in the vicinity.

The following plants make up the menu of this beetle: Lamb's-quarters, green-berried nightshade, spinach, and sugar beets. Squash and pumpkin vines are sometimes damaged. The adults also feed upon alfalfa.

If none of the weeds upon which it feeds are growing in a neighborhood the spinach carrion-beetle is not apt to occur in injurious numbers.

NATURE OF INJURY

Both the adult beetles and the larvae feed upon sugar beets. The edges of the leaves are eaten, the injury being quite characteristic in its appearance. According to Prof. R. A. Cooley,* the gnawed margins of the leaves are ragged, often showing a thin projection of crushed tissue.

Injury to sugar beets most often occurs near roadsides, ditch banks, fence rows, and grain and alfalfa, from which the insects migrate into the beet fields.

Sugar beets are seldom injured after they have attained any size. The greatest damage occurs about blocking and thinning time, when many plants may be completely gnawed off.

METHOD OF CONTROL

Clean Culture

Much can be done to control this pest by destroying the weeds upon which it feeds. However, the work should not end here. The beetles hibernate in the soil along ditches, fence rows and roadsides. If all weeds are burned from these waste lands and the soil thoroughly disced or plowed in the fall, few beetles will select these bare spaces for hibernation. If the weeds and trash are left, these places are inviting hibernating grounds, especially if a few of the host plants already mentioned are growing on them.

Poisoned Bait

In the article* already referred to, Prof. Cooley states that the poisoned bran mash so effective in the control of cutworms (See "Kansas Mixture," page 39) is very effective against the carrion-beetle when

*"Spinach Carrion-beetle," Journal of Economic Entomology, Vol. 10, No. 1 (1917).

spread on waste land, about ditches and fields. As the beetles and larvae feed principally at night the poisoned bait to be most effective should be put out late in the day.

DESCRIPTION

The Egg

The eggs, which are laid in the soil, vary from almost spherical to oval in form. The size is also variable. The smaller ones are about $\frac{5}{64}$ of an inch long and the larger ones $\frac{3}{32}$ of an inch long. The color is a creamy white, and the surface is polished and glistening. Prof. Cooley has observed that the eggs increase in size after being laid.

The Larva

The newly hatched larva is about $\frac{3}{16}$ of an inch long and black in color. When fully grown the larva appears as shown in Figure 11, Plate VII, Page 23. The color is a shining black. The head of the insect represented by the figure is bent downward, making it appear as though the first segment of the thorax were the head. The young carrion-beetles are flat, and the body, which is composed of plates each terminating in an acute angled corner at each side, has the appearance of being notched on the margin.

The Pupa

The pupa is white and soft. The legs, antennae and wings are free. At the sides of the body there are several long hairs and at the tip are two fleshy prongs also terminated by long hairs.

The Adult

The adult beetles (Fig. 10, Plate VII, Page 23) are uniformly dull black. The wing covers are ribbed lengthwise. The Latin name of the beetle, "bituberosa," meaning "with two tubercles," was suggested by the tubercles at the end of the two outside ridges.

LIFE HISTORY

Egg laying begins about the middle of May and continues until nearly the middle of July. The females seem to prefer moist soil as a place to deposit their eggs, which are laid from one to two inches below the surface. Prof. Cooley reports as high as 75 eggs from one female, the average of several being 39. The eggs hatch in from three to six days.

The larval stage lasts about 24 days, at the end of which time the full grown larva enters the ground, forms an oval cell and pupates. The pupal stage lasts 23 to 26 days, the insect completing its development from the egg to the adult in about 55 days.

After emerging from the pupae the adults spend the remainder of the season in the soil, coming out occasionally to feed. They spend the winter in hibernation about the margins of fields, on ditch banks and roadsides, coming forth as soon as the frost leaves the ground in the spring. There is no evidence of more than one brood each season.

(e) BLISTER-BEETLES

(Figs. 8, 9, 12 and 13, Plate VII, Page 23)

In nearly all lists of insects attacking the sugar beet mention is made of several species of blister-beetles. The economic status of some of our common species is difficult to determine, as the larvae, by destroying grasshopper eggs, render a real service to agriculture, while the adult beetles damage certain crops by feeding upon their leaves.

A powder made of the dried bodies of the adult beetles is used in the treatment of certain diseases and injuries. When applied to the flesh in a paste form blisters are produced. This led to the beetles being called blister-beetles. The powder made from the dried bodies of a European species is known in the commercial world as Spanish-fly.

NATURE OF INJURY

The injury to crops (which is the result of the feeding of the adult) is similar to that caused by other leaf-eating beetles.

These beetles are strong fliers, often appearing in swarms on sugar beets, potatoes and other crops, where they feed most ravenously for a time. Disappearing as suddenly as they come, they leave only the riddled remains of the crop.

At such times applications of poisons are of little avail because of the great numbers of beetles and because of their voracity. Only the promptest action and most thorough application of whatever remedies are employed against them will be effective.

METHODS OF CONTROL

Poison

As already stated, the use of poison is seldom effective. If poison is used, 2 to $2\frac{1}{2}$ pounds of Paris green or 4 to 5 pounds of dry arsenate of lead, or 8 to 10 pounds of arsenate of lead paste, should be used in the quantity of water necessary to spray one acre. This varies from 50 to 100 or 125 gallons in the different types of sprayers.

Mechanical Measures

As the beetles are very active and readily put to flight, driving them from a field is often the most effective means of preventing losses. This can be done by several persons, armed with brush or small branches of of trees, driving the beetles ahead of them. Always work in one direction, taking as wide a strip across the field as possible, and going with the wind.

According to Dr. Chittenden*, a windrow of dry straw or hay placed along one side of the field can be burned after the beetles have been driven onto it, thus destroying them.

When small areas or gardens are attacked the beetles can sometimes be knocked into pans containing a small quantity of water covered with a thin film of kerosene. This method is not suited to large fields.

When the beetles are not very numerous they can be dispersed and serious damage prevented by using the cultivator equipped as suggested for scattering flea-beetles, i. e., with pieces of rope or strips of canvas attached to the frame so as to drag on the plants.

*"A Brief Account of the Principal Insect Enemies of the Sugar Beet," Bulletin No. 43, Division of Entomology, U. S. Department of Agriculture (1903).

DESCRIPTION AND LIFE HISTORY

The blister-beetles are especially interesting because of the feeding habits of their larvae and because of the fact that they pass through more stages in the course of their development than any of the other beetles discussed in this Bulletin. There are six stages, the egg, three larval, the pupal and the adult.

Mention has already been made of the fact that the larvae of some species feed upon grasshopper eggs. The seasonal history of these may be summarized as follows:

The Egg

The eggs, which are small and oval in form, are very delicate. They are deposited in loose clusters in holes in the ground which have been excavated by the female blister-beetle. After the eggs are laid they are covered with loose soil which the beetle scratches over them with her feet.

The places chosen for egg laying are just those warm sunny spots chosen by the female grasshopper for the same purpose. Thus we see that the newly hatched blister-beetle finds an abundance of food close at hand when it emerges from the egg.

The First Larval Stage

When the larva escapes from the egg its head is large and the jaws are well developed. Its legs are comparatively long and the body slender.

As soon as the body walls become hardened by exposure to the air the active larva starts in search of a grasshopper egg-pod. When one is found the larva gnaws its way into it and begins feeding upon the eggs.

At the end of its first meal of uncooked omelet, which may last for three or four days, the larva spends the next few days resting, and about the eighth day after beginning to feed the first molt takes place and the second larval stage begins.

The Second Larval Stage

In this stage the body is much more robust and the legs are much shorter than before. After feeding for about a week another molt takes place.

The legs and mouth are now rudimentary and the body resembles that of the white grub.

After about six or seven days the skin is once more shed and what is known as the ultimate stage of the second larva is begun. In this stage the larva feeds more voraciously.

After a week of almost continuous feasting the larva leaves the remains of its repast and burrows a short distance into the soil, where a smooth cell is formed.

Within this cell another change takes place. About the third or fourth day the skin splits over the head and is gradually worked backward but is not entirely shed. The mouth and legs are now quite rudimentary, being represented by small tubercles. The skin becomes quite rigid and takes on an orange yellow color (Fig. 12, Plate VII, Page 23). This is the pseudopupa or coarctate larva.

The winter is spent in this form. In the spring the hard coarctate larval skin is cast off and the third larval form appears.

The Third Larval Stage

In this stage (Fig. 13, Plate VII, Page 23) the larva is robust of body, and while the mouth parts and legs are well developed, it does not appear to feed.

After burrowing about in the soil for a time the third larva changes to the pupa.

The Pupa

The pupa is white at first, becoming darker as the time for the emergence of the adult approaches. The legs, wings and antennae are free, as in the pupa of the alkali-beetle.

The pupal stage lasts from five to six days, when the adult beetle appears.

The Adult

The adult blister-beetles are slender, rather soft bodied insects. In fall they are common objects on the flower clusters of goldenrod and other plants.

The black blister-beetle (Fig. 8, Plate VII, Page 23) feeds upon Russian thistle and goldenrod blossoms, as well as potatoes and other crops.

The ash-gray blister-beetle (Fig. 9, Plate VII, Page 23) is quite common in alfalfa fields in Northern Colorado, where it feeds upon the leaves of the alfalfa.

3. GRASSHOPPERS

During the early seventies the rich prairie soils of western Minnesota attracted many homesteaders, so that by the summer of 1876 (which is known as one of the worst grasshopper years in the history of American agriculture), the vast expanse of these prairies was dotted with claim shanties, tree claims and green fields.

The first of June of this memorable summer all crops gave promise of a bountiful harvest. Then vague rumors of great hordes of Rocky Mountain locusts, which were destroying crops to the southwest, caused much apprehension among the settlers, many of whom had spent their last dollar in the planting of their crops, fully expecting the harvest to be sufficient for their future needs.

About June 20th great swarms of hoppers began flying over, coming from the northwest and always traveling to the southeast. At times the swarms were so large and the hoppers flew in such dense bodies that one could look directly toward the sun without hurting the eyes. The light was dimmed as though a thin cloud obscured the sun.

The suspense of the homesteaders had almost reached the breaking point when the wind changed and the long dreaded thing happened. Suddenly, about ten o'clock in the forenoon of July 5th people were startled by a loud, rushing sound like that of an approaching storm. Upon going outside a sight long to be remembered met their eyes.

From the sky, like huge snow flakes, millions of Rocky Mountain locusts were dropping to earth. This living shower lasted for about half an hour, when it ceased as suddenly as it began.

The ground was literally covered with a seething, kicking mass of hoppers three to four deep. Gradually this struggling horde became quiet, resting in regularly arranged rows and layers. In this position they remained for about four hours, when the work of devastating the fields began. Their work was rapid and thorough and the destruction complete.

The writer's father describes the work of these hoppers in a corn field as follows:

"After having rested for about four hours those hoppers next to the corn stalks began to feed upon them near the ground. As this weakened them the stalks fell and were immediately attacked by other hoppers. Stalk after stalk fell, until about sundown, when feeding ceased for the day, less than a hundred stalks remained standing in a $4\frac{1}{2}$ acre field. When the hoppers left this field not a vestige of the crop remained excepting the stumps of the corn."

Garden truck, with the exception of peas, was also completely destroyed. Root crops such as beets and turnips were eaten leaf and root. Where each plant stood only a hole in the ground remained. As they devoured these roots the ravenous hoppers fought for a place until their bodies and extended legs resembled a bundle of sticks set on end in a small bowl.

The third day the hoppers rose and started in a southeasterly direction. They disappeared as suddenly as they came, leaving only bare ground and disheartened farmers behind over an area one hundred miles square.

Nothing more was seen of the hoppers until early August, when a second but smaller swarm settled on the cropless country covered by the earlier one. This second swarm found little but the prairie grasses to feed upon. However, this furnished sufficient food for them until they had honeycombed fields and prairie with their egg pods.

The following spring the whole country was a hopping mass of young Rocky Mountain locusts. Then began the fight to destroy this growing army and save what crops had been sown.

All the young hoppers traveled in one direction. Whichever way they started in the morning was the direction for the day. While they were still small, trenches were dug in front of them into which they fell and in which they were buried.

The hopper dozer played its part in the fight against the young hoppers as they became larger and more active. By constant fighting some crops were partially saved, at an enormous cost of time and hard work.

About the first of June the hoppers, having acquired wings, took flight for parts unknown.

With the exception of very local outbreaks, which have been quickly brought under control, the Rocky Mountain locust has never since appeared within the bounds of the vast territory devastated during 1875 to 1877. In those parts of its range where it was most numerous during these years it is almost unknown at the present time.

Thus one of the most destructive insects of the Western Hemisphere came, devastated vast areas of crops and passed on, never since to appear in anything like the same numbers in any part of its former range.

While the Rocky Mountain locust has almost ceased to be a pest, there are several other species of grasshoppers which frequently occur in great numbers and do much damage to crops within restricted areas. Three of these species—the two-lined hopper, the differential hopper and the red-legged locust—are worthy of special mention.

(a) TWO-LINED HOPPER

(Figs. 9, 10 and 11, Plate IV, Page 17)

The two-lined hopper, together with the two following species, often occurs in large numbers in the Great Plains area.

It is easily distinguished from our other injurious species by the two light lines beginning at the eyes and extending along the back and meeting at the tip of the wings.

The females, one of which is shown, natural size, in Figure 10, Plate IV, Page 17, are larger than the males. The color of both sexes is yellowish or tan color, with darker, almost black markings. Some of the males are much darker than the females, there being very little yellow visible on these dark individuals. However, the light lines mentioned above are always clearly discernible.

(b) DIFFERENTIAL HOPPER

(Figs. 12 and 13, Plate IV, Page 17)

Many times the differential hopper outnumbers the preceding one. Since the passing of the Rocky Mountain locust it has been one of the principal injurious forms in the Great Plains area.

This hopper occurs in two colors, with many intermediate shades. Figure 12, Plate IV, Page 17 represents a male of the light or yellow phase, while Figure 13, Plate IV represents the opposite color extreme.

In size this hopper resembles its near relative, the two-lined hopper. However, in all its color variations, it can be distinguished from the two-lined hopper by the lack of the two pale lines on the back.

(c) RED-LEGGED LOCUST

(Figs. 14 and 15, Plate IV, Page 17)

The red-legged locust may be taken as representative of a group of small or medium sized species which have in the past been responsible for widespread damage to crops.

In general appearance and size the red-legged locust resembles the Rocky Mountain locust already referred to, the lesser migratory locust, and the California devastating locust.

It is very difficult to give a popular description of this grasshopper that will make it possible for one not trained in entomology to distinguish it from the other three species mentioned in the preceding paragraph.

Figure 14, Plate IV, Page 17 represents an average male, natural size. The females are somewhat larger. The color of this hopper is variable, being brownish, shaded with almost black in the darker individuals. In the light individuals, the lighter portions are yellowish brown.

The slender part of the hind legs is usually reddish, although in some specimens it is yellowish or even pale green.

NATURE OF GRASSHOPPER INJURY

Grasshoppers belong to that group of leaf-feeding insects which bite their food. The crops attacked are often completely defoliated, and in the case of root crops such as sugar beets, turnips and others the roots are often eaten as well. The crowns of sugar beets are often completely destroyed and as a consequence the beets soon die, as they cannot develop new leaves.

Young alfalfa is often destroyed by grasshoppers, especially where the ripening of the grain used as a nurse crop forces them to seek other green food.

When attacking oats, grasshoppers have the peculiar habit of gnawing off the kernels, which they seldom if ever eat.

When other food fails, shade trees and shrubs are attacked and stripped of their leaves.

During recent years grasshopper injury has usually occurred near wild land or waste land about the borders of fields, roadsides, ditch banks and fence rows, which are favorite breeding grounds of all grasshoppers. With the passing of the Rocky Mountain locust the migration of large swarms of grasshoppers from long distances appears to be a thing of the past.

METHODS OF CONTROL

Kansas Mixture

The most effective remedy employed in the control of grasshoppers is the poisoned bran mash known as "Kansas Mixture," which is made of the following ingredients:

Bran	25 lbs.
Paris green	1½ lbs.
Molasses	2 qts.
Lemons	5
Water, about	3 gals.

It will be noted that the formula for use against grasshoppers is slightly different from that given on page 39 for use against cutworms.

How to Prepare the Mixture

In preparing this mixture proceed in the following manner: Thoroughly mix the bran and Paris green while dry until the whole has a uniform greenish color. Take about two gallons of water and add to this the molasses and lemons after the latter have been finely ground, rind and all. Stir this mixture until the molasses is completely dissolved, then pour it over the bran and Paris green. Mix until evenly moistened, then add water a little at a time until the mash is just wet enough to stick together well but yet dry enough to crumble readily when being spread.

When to Apply the Mixture

Grasshoppers spend the night on weeds and other plants well up above the ground. Not until after the sun rises and they have become warmed do they become active and begin feeding. After their night's fast the hoppers are hungry, so that if the poisoned bran is scattered before they begin feeding in the morning the best results are secured. If

the mixture is put out in the evening it loses much of its odor during the night and is less effective as a result. When put out after the hoppers have filled up in the morning they are less hungry and do not eat so freely of the bait as earlier in the morning. Then by the time they are ready for another meal the sun has dried it more or less, which makes it less appetizing.

Also, apply the remedy in the early part of the season, while the hoppers are small. "It is the early bird that catches the worm." Likewise it is the early farmer that gets the hopper.

How to Apply the Mixture

The Kansas Mixture should be thinly broad-casted over the ground. The most satisfactory way is to sow it by hand, using the same motion as in sowing grain or grass seed by hand. Care should be exercised to prevent leaving large lumps in the spreading, as these are apt to be eaten by live stock or poultry and cause their death. The mixture made with quantities, according to the formula given, is sufficient to cover $4\frac{1}{2}$ to 5 acres. If thinly and evenly applied to this area there is no danger of either live stock or poultry being killed by feeding on treated land.

Where to Apply the Mixture

The poisoned mash should be scattered on waste land, borders of fields or other places where the hoppers congregate for the night.

The Hopper Dozer

During the years 1875 to 1877 many devices for destroying grasshoppers, especially the wingless, young hoppers, were invented and covered by patent rights. The inventors of some attempted to use sulphur fumes to kill the hoppers, others crushed them between rollers, and still others used the principle of the vacuum cleaner to suck the hoppers into their machine.

Fig. 15. Hopper Dozer (After Chas. R. Jones, Bulletin No. 233, Colorado Agricultural Experiment Station)

Of this assortment of mechanical hopper killers only the hopper dozer (Fig. 15, Page 102), as we know it today, has survived. This device has long been recognized as effective in destroying grasshoppers, but its usefulness is confined to low standing crops, mown meadows, stubble fields and relatively flat ground. Where the ground is rolling or hilly the "live hopper machine" takes the place of the dozer.

The hopper dozer consists of a sheet-iron pan about 4 inches deep and 12 to 16 feet long by $2\frac{1}{2}$ to 3 feet wide. This is separated into compartments by cross partitions, making the compartments about square. These cross partitions are to prevent the liquid used in the pan from running to either end when the dozer is used on slightly rolling ground. This pan is placed on runners made of 2x4 or 2x6 lumber. At the back and ends of the pan is an upright sheet of tin or oilcloth $2\frac{1}{2}$ or 3 feet high, against which the hoppers fly and are knocked or slide down into the pan.

When in operation the pan is partially filled with water covered with a thin film of kerosene. As the hoppers accumulate in this liquid they are skimmed off. If this is not done the falling insects are prevented from becoming coated with the oil and water, which is necessary in order to kill them. The dozer is drawn by horses, one hitched at either end.

A dozer of this sort can be built on the farm, and should be constructed for $6.00 to $7.00 when normal prices prevail.

The Live Hopper Machine

This device, which is of more recent origin than the dozer, is especially adapted to use on rolling or hilly land where those devices which employ liquids cannot be satisfactorily worked.

The live hopper machine consists of a box about 2 feet wide, 2 feet deep and 16 feet long, with bottom and ends of wood, and top and back of fine screen. The remaining side of the box is partially closed by a curved sheet iron or tin deflector about three feet high and extending along its entire length. The deflector reaches to within about three inches of the bottom of the box, the lower edge being curved backward into it. Just in front of this is a narrow strip of tin fastened to the bottom of the box directly under the bent-in portion of the deflector and curved outward and upward to a height of about six inches. Thus a curved mouth is produced along the entire length of the box. The hoppers flying against the deflector slide down into this mouth. The narrow strip of tin mentioned prevents the hoppers from escaping by hopping off of the machine in front. Once in the mouth of the box, the light coming through the screen attracts them and the hoppers enter it in an attempt to escape, and are imprisoned.

At each end of the box is a door which is used in removing the hoppers from the machine after they have been killed by being sprayed with kerosene.

The machine is placed on runners and drawn by horses in the same manner as the dozer.

Harrowing and Discing

Even though the hopper dozer is used and the Kansas Mixture applied, many grasshoppers will reach maturity and many eggs will be laid each fall. In order fully to round out the season's work against the grass-

hopper plague, all waste land should be thoroughly harrowed or disced. This harrowing and discing will break up the egg pods and scatter the eggs where exposure to the air and weather will destroy them.

Many eggs will be deposited in alfalfa fields. The practice of renovating this crop with some one of the various makes of alfalfa renovators not only destroys many grasshopper eggs, but benefits the crop as well. Early spring or fall renovating is most effective in destroying grasshopper eggs.

Plowing

Next to harrowing and disking, plowing egg infested land is one of the most effective cultural means of preventing hopper losses. Plowing alone does not destroy many of the eggs, but if the soil is plowed to a depth of four to five inches and the surface thoroughly worked with the harrow, a very small proportion of the young hoppers will succeed in making their way to the surface.

Clean Culture

Our injurious species of grasshoppers prefer weedy or grassy land as places to deposit their eggs. If all waste land about fields, ditches and fences is kept free of vegetation, few eggs will be deposited and adjoining fields will be comparatively free from injury.

Poultry

Poultry, if allowed to run at large, will rid considerable areas of grasshoppers. Turkeys are more valuable for this purpose then hens, as they range farther and spend more time in the fields. A small flock of turkeys is a double source of profit to the farmer.

LIFE HISTORIES OF GRASSHOPPERS

The life histories of our most injurious species of grasshoppers are very similar.

The mature females usually select some dry sunny location covered with a growth of weeds or bunches of grass for depositing their eggs. The eggs are deposited in holes in the soil which are lined with a glue like substance secreted during egg laying. When this becomes hardened it protects the eggs from excessive drouth, moisture, and possibly to some extent, from predacious insects or egg parasites.

In making these holes the female presses the tip of her abdomen, armed with four hard, curved and pointed plates (See Figs. 10 and 11, Plate IV, Page 17), against the soil. By alternately opening and closing these plates the soil is forced aside.

When the hole is filled with eggs it is sealed with more of the glue-like secretion. This egg cluster inclosed within its impervious case is called an egg pod. Figure 8, Plate IV, Page 17 represents one of these egg pods removed from the soil. A portion of the covering has been removed near the upper end, exposing the eggs. The eggs are of a yellowish or olive yellow color, about one-fourth of an inch long, cylindrical, and slightly curved. Most females deposit two egg clusters, the total number of eggs laid varying from 50 to 100 or more.

All of our injurious grasshoppers pass the winter in the egg stage. There are several species, however, that hatch in the fall and hibernate in an immature state, completing their development the next summer.

Their presence about fields during warm weather in winter is responsible for many reports of early hatching of grasshopper eggs.

Hatching begins during late May and early June and extends over a considerable period of time. Those eggs deposited on sunny, south slopes and in other protected locations hatch first.

The young grasshoppers or nymphs (Fig. 9, Plate IV, Page 17) resemble the adults but lack the wings of the latter. During their development they shed their skins several times. With each molt they resemble the adults more closely. Just before the last molt they appear as shown in Figure 1, Plate V, Page 19. At this time the wings are represented by four pads on the back of the insect.

During the process of molting, grasshoppers cling to some plant to which the cast skin often remains fastened for some time.

With the last molt the grasshopper becomes an adult with fully developed wings. Mating soon takes place and egg deposition begins, usually, about the middle of August and continues until cold weather kills the grasshoppers.

NATURAL ENEMIES

Flesh Flies

The larvae of several species of flies belonging to a family popularly known as "flesh flies" are parasitic upon grasshoppers.

Figure 3, Plate IV, Page 17 represents a flesh fly [7] which was reared from the two-lined hopper. The larva or maggot of this fly is shown in Figure 4, Plate IV.

The flesh flies here referred to are viviparous, which is to say that they give birth to living maggots instead of laying eggs.

Mr. E. O. G. Kelley* describes the manner in which one of these flies places its larvae upon the host hopper substantially as follows:

While the hoppers are on the wing the female flesh flies strike them on the under side of the lower wing, at the same time depositing a tiny maggot near its margin. When struck the hopper drops to the ground. The maggots were observed by this author to crawl along the margin of the wing to its base and then to enter the hopper's body through some natural opening or tender tissue. Once within the hopper the maggots feed upon its body fluids until mature. The hoppers usually live until the maggots are nearly full grown. However, these parasitized hoppers are apt to be sluggish and inactive several days before their vitals are destroyed and they die. When mature the maggots leave the dead hopper, burrow into the ground or conceal themselves underneath trash, change to pupae and later into adult flies.

The flesh flies are foremost in the list of insect enemies of the grasshopper and are of the greatest value to agriculture. They seldom appear in buildings in numbers, being denizens of the fields where their good work is done.

Ground Beetles

Several species of beetles commonly known as ground beetles (See page 130) are known to feed upon grasshopper eggs as well as the grasshoppers, especially in their immature stages.

*"A New Sarcophagid Parasite of Grasshoppers," Journal of Agricultural Research, Vol. II, No. 6 (1914).

(7) See explanation of "Reference Figures," page 2.

The egg-eating Amara (Figs. 20, 21 and 22, Plate IX, Page 27) belongs to this family and is of especial interest because of the good work its larvae did in destroying eggs of the Rocky Mountain locust in the territories overrun by this insect in 1876 and 1877.

Fig. 16. Exposed Grass Roots, showing Grasshopper Eggs and Larvae of the Ground Beetle, *Amara obesa*

Wherever grasshopper eggs are plentiful, the larvae (Fig. 20, Plate IX, Page 27) of this beetle will be found. These whitish yellow grubs with brown heads and dark shields on each segment of the body burrow among the roots of grasses (Fig. 16, Page 106), where the female grasshoppers have deposited their eggs, and destroy them in large numbers.

The change from larva to pupa (Fig. 21, Plate IX, Page 27) takes place during early May and the adult beetles (Fig. 22, Plate IX, Page 27) emerge two or three weeks later.

Blister-beetles

The part which the larvae of blister-beetles play in the destruction of grasshopper eggs has been discussed on page 96. However, the good work of these larvae is partially offset by the adult beetles feeding upon crops.

Locust Mites

The locust mite (Figs. 1, 2, 17 and 18, Plate V, Page 19) is one of the most interesting as well as important enemies of the grasshopper. This little creature, which is closely related to the "chiggers" so common in some parts of the country, is not an insect but belongs to the same class of invertebrate animals as the spider.

The animals of this class, which includes the scorpions, harvestmen, spiders, mites, ticks and others, differ from the true insects in having four pairs of legs instead of three pairs in the adult stage and in having the head and thorax grown together. However, the immature stages often have but three pairs of legs.

During those years when the Rocky Mountain locust overran the country west of the Mississippi river the ground was, at times, almost red with locust mites.

The adult female (Fig. 17, Plate V, Page 19) deposits her eggs, a few of which are shown above the figure, in clusters of from 300 to 400. These are placed below the surface of the soil, often to a depth of $1\frac{1}{2}$ to 2 inches. The adult male, which is smaller than the female, is shown in Figure 18, Plate V, Page 19.

In due time the minute, orange-red larvae, one of which is shown much enlarged in Figure 2, Plate V, Page 19, emerge. These larvae possess but three pairs of legs. However, they are very active and soon become attached to a grasshopper as shown in Figure 1, Plate V, Page 19. Usually the young mites are found under the wing pads when there are but a few on an individual.

These mites are sometimes mistaken for the red eggs of some parasite.

The bodies of the young locust mites become distended in true tick fashion after feeding on a grasshopper and drop to the ground, moving about with difficulty in this condition. After secluding themselves under trash or among the clods on the surface of the soil the change to the pupa and from the pupa to the adult takes place. The adults, which feed upon the eggs of grasshoppers, spend the winter secluded beneath any object which furnishes protection from the weather.

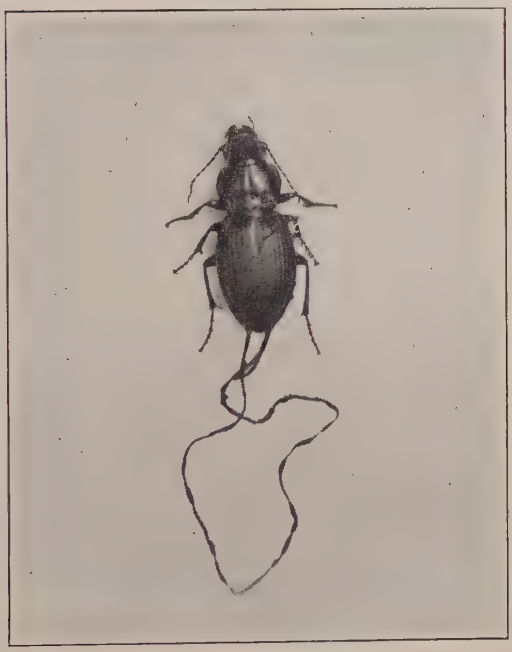

Fig. 17. Hair Worm escaping from a parasitized Ground Beetle

Hair Worms

The hair worms or hair snakes (Fig. 17, Page 107, Fig. 18, Page 108, and Fig. 16, Plate IV, Page 17) are still believed by some to be animated horse hairs. Even those knowing the fallacy of this old belief do not always know the relation of these worms to other living creatures. The majority of those hair or "Gordian worms" observed swimming about in stagnant pools or the margins of streams and in irrigation ditches belong to the genus *Gordius*.

The worms of this group are parasitic within insects. The eggs are laid in water, usually in the spring, and in the course of a week or ten days the young worms emerge. They are armed with piercing mouth parts with which they force their way into the body of some insect where they become encysted in its muscles. This insect is in turn eaten by some other within which the encysted hair worm completes its development. Many Rocky Mountain locusts were destroyed by these worms during the outbreak of this insect

in the seventies. Infested grasshoppers have a pale, sickly appearance and are more or less sluggish in their movements.

Ground beetles are also often infested. Figure 17, Page 107 shows a common species just as the hair worm is emerging. Figure 18, Page 108 shows the worm after freeing itself from the beetle. Figure 16, Plate IV, Page 17 represents a mature male hair worm taken from a ground beetle.

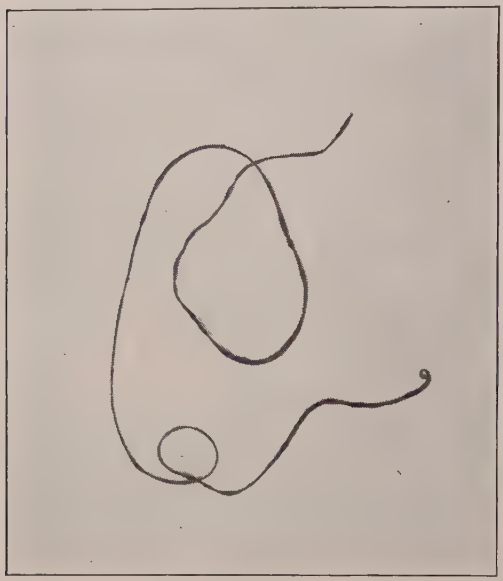

Fig. 18. The Hair Worm shown in Figure 17, after it had escaped from the Beetle

Birds

A discussion of the natural enemies of the grasshopper would not be complete without mention of some of the many birds which assist in holding this pest in check.

The list of birds which render a real service to agriculture by destroying grasshoppers includes some which are not in very good standing because of occasional damage to crops or raids upon the poultry yard or orchard, and because of a lack of knowledge of their feeding habits throughout the entire year.

Generally speaking, all owls are looked upon as undesirables and as the legitimate prey of the hunter. As a matter of fact, with the exception of the great horned owl, these birds do far more good than harm. The occasional young chicken or turkey which they steal is small pay for the many mice, ground squirrels and other injurious rodents which they kill, to say nothing of the grasshoppers which some destroy.

The long-legged burrowing-owl, which inhabits deserted prairie dog burrows, feeds very largely upon grasshoppers during those months when these insects are plentiful. As individuals they are among the most effective feathered grasshopper destroyers.

While blackbirds are not so effective as individuals, their great numbers make them of even greater value than the burrowing-owls.

The red-headed woodpecker is quite generally condemned for pecking holes in buildings, eating fruit and occasionally damaging other crops. Despite his bad habits, this bird is not without good points. Over seventy different kinds of insects enter into this bird's bill-of-fare, which includes many crop pests, among them large numbers of grasshoppers.

Together with the owls, hawks enjoy a bad reputation among rural communities. It has been stated that of over seventy species of hawks

and owls found in the United States but six are considered really injurious. These are the gyrfalcon, duck hawk, sharp-shinned hawk, Cooper's hawk, goshawk and great horned owl.

The little sparrow hawk and the large, dark brown Swainson's hawk are noted insect eaters. Both of these feed freely upon grasshoppers.

Fig. 19. Grasshoppers killed by the Fungous Disease, *Empusa grylli*

Fungous Diseases

During late summer numbers of dead grasshoppers are always observed clinging to weeds and other plants along the roadside or field border. These have been killed by a fungous disease (*Empusa grylli* Fres.). Grasshoppers attacked by this disease climb to the top of some plant when about to die and clasp it with their fore legs. (Fig. 19, Page 109). In this position they die and remain clinging until their bodies become so decomposed that they fall to the ground.

This seems to be the most common disease attacking grasshoppers. However, there are several other fungous as well as bacterial diseases which destroy some grasshoppers nearly every year.

4. FIELD CRICKETS

(Fig. 7, Plate IV, Page 17)

Crickets are familiar objects during late summer and early fall. Their lively chirping during mild fall evenings seems to add to the general spirit of harvest cheer. Yet these dusky cousins of the grasshopper are not without their bad habits. In fact, they are noted for their appetites and their liking for such articles as binder twine, clothes, carpets and

rugs. Sugar beets are also sometimes attacked. The leaf stems are often eaten and deep pits are eaten in the crowns of the beets. Figure 7, Plate IV, Page 17 represents an immature female field cricket.

5. LEAF-MINERS

Thus far in our discussion of leaf feeding insects only those which feed exposed on the surface of the leaves have been considered. There is another group of leaf feeders, however, which live protected within galleries, or "mines," as they are popularly called, which result from the eating away of the pulp of the leaves while the outer portion or epidermis is left untouched. Some of these mines are serpentine in form, while others are irregular in shape, becoming unsightly and discolored as the season advances.

Several species of leaf-miners are known to attack sugar and garden beets and mangels. However, only the following species appears to do any considerable damage to the sugar beet crop.

(a) BEET OR SPINACH LEAF-MINER

(Figs. 1, 2, 3, 4 and 5, Plate III, Page 15)

NATURE OF INJURY

The beet leaf-miners burrow into leaves and feed upon the pulp. At first the mines appear as tortuous whitish or brownish lines on the blade of the leaf. As the miners increase in size the mines become large, irregular areas, as shown in Figure 1, Plate III, Page 15.

While still inhabited the mines may have a watery appearance, and in case the greater part of a small leaf is mined out the leaf droops and appears to be decaying. If such leaves are held between the observer and a strong light the miner can be seen within, usually near the side of the mine.

If the weather is very warm, dry beet leaves may wilt and lie on the hot soil during very warm days. Sometimes portions of these leaves are killed by the heat. These dead areas often appear very similar to the deserted mines of leaf-miners. They can be distinguished from them very easily, however, by the fact that the pulp still remains, there being no cavity between the upper and lower surfaces of the leaves.

Ordinarily the damage to sugar beets is so slight that no account need be made of it. Occasionally, however, the miners are so numerous that they materially injure a crop. The destruction of the inner portion of the leaves has the same effect as though the entire leaf were destroyed.

METHODS OF CONTROL

It is doubly fortunate that the injury is usually so slight that remedial measures are not required, as there is no known remedy practical for field use. Several poisons have been tried, but all have proved unsatisfactory.

Picking Infested Leaves

In the case of small gardens the infested leaves can be picked off and destroyed. This will prevent the rapid multiplication of the miners.

Clean Culture

As in the case of many other insect pests, preventive measures are of more value than curative ones. The beet leaf-miner feeds in the leaves of lamb's-quarters, or white pigweed, as it is sometimes called. The destruction of this weed will do much to reduce the number of miners in a vicinity.

DESCRIPTION AND LIFE HISTORY

The Egg

The eggs, which are placed on the under side of the leaves of the host plants, are shown natural size in Figure 1 "A," Plate III, Page 15. Usually they are laid side by side in groups of from two to five or six. Their surfaces are finely reticulated. Figure 2, Plate III, Page 15 represents three eggs much enlarged, showing this reticulation of the surface.

The Miner

The miner (Fig. 3, Plate III, Page 15) hatches in about four days. It is a whitish maggot, pointed at the head and broadening toward the opposite end. When fully grown it is about one-fourth of an inch long. As soon as hatched it burrows into a leaf and begins to feed upon the pulp.

The Pupa

At the end of seven or eight days the fully grown miners drop to the ground and after burying themselves just below the surface or beneath trash lying on it, they pass into the pupal stage within the puparium (Fig. 4, Plate III, Page 15). The pupal state lasts from ten to twenty days during warm seasons of the year. The last generation of miners in the fall is thought to pass the winter in the pupal stage, the flies emerging the next spring.

The Adult

The adult miner (Fig. 5, Plate III, Page 15) is a two-winged fly belonging to the same order as the common house fly. This fly has no very distinctive markings. The face is silvery white between the eyes, which are brownish. The body, which is dull grey, is sparsely covered with quite long stiff hairs.

B. SUCKING LEAF FEEDERS

(Aphids or Plant-lice, True Bugs, Leaf-hoppers)

1. APHIDS OR PLANT-LICE

Aphids, or plant-lice, as they are commonly called, are small, soft-bodied creatures which usually feed in compact masses on the stems, leaves or roots of plants. Some feed exposed upon the plant (Fig. 20, Page 112), others cause the leaves upon which they feed to curl over them (Fig. 21, Page 112), and still others, like the sugar beet root-louse, spend a part of the season, at least, within galls produced by their feeding upon the host plant (Fig. 22, Page 113).

Fig. 20. An exposed Colony of Plant-lice on a common roadside Weed

Fig. 21. Leaves of White Ash curled by a Plant-louse

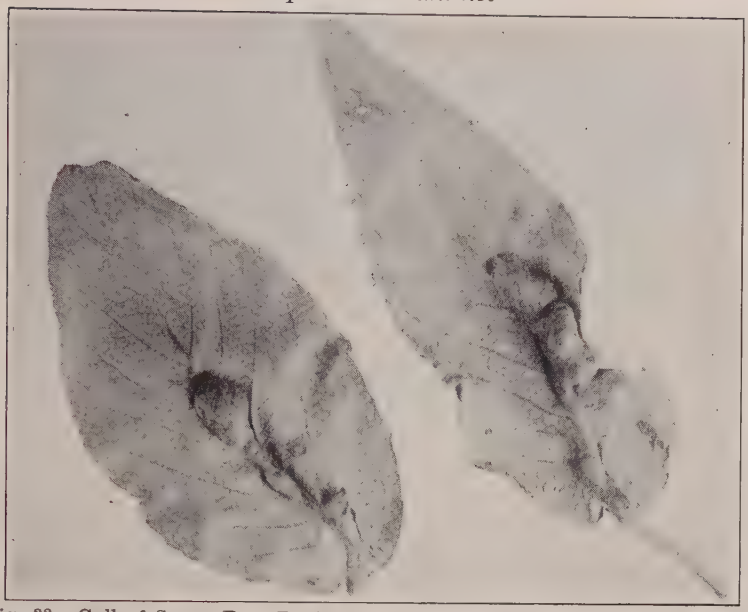

Fig. 22. Gall of Sugar Beet Root-louse on Leaves of Narrow-leaf Cottonwood

Fig. 23. A common Wingless Aphid; Honey Tubes at "A"

NATURE OF INJURY

The indications of aphid infestation are varied, the different plant-lice affecting their hosts differently. A slow growth associated with wilting of the leaves, which are apt to be a pale yellowish green, is characteristic of root-louse attack.

Most lice which feed above ground prefer the new, soft growth of plants. If the leaves and new growth wilt, if the leaves are covered with a sticky, sweetish substance called "honey dew," or if they become curled and distorted, plant-lice are very likely present.

Ants are very fond of honey dew and in order to secure it are known to care for aphids and their eggs, exhibiting in this an instinct which amounts almost to reasoning. Ants and aphids are so closely associated that the presence of the former on a plant is a very good indication that the latter are present also.

METHODS OF CONTROL

The stomach poisons used in the control of biting insects will not kill plant-lice. Contact poisons must be used. Even then, the control of those aphids which live within galls or curled leaves is very difficult unless the remedy is applied during the season when the lice are in the egg stage or just as the eggs begin to hatch in the spring. After these lice once become inclosed within the galls or leaves it is impossible to reach them with any contact spray. Several species are so covered with a flocculent secretion that a spray must be very thoroughly applied and with considerable force to be effective.

Kerosene Emulsion

Where only a few plants in the garden or a small number of ornamental shrubs are to be treated, kerosene emulsion has long been a standard remedy because of its simplicity and the fact that all the ingredients required in its making are always at hand.

This contact poison is usually made in the form of a stock solution, in which form it can be kept for several weeks. When used it is diluted by adding water. The stock solution is made as follows:

Mix one-half pound of common laundry soap or whale oil soap in one gallon of water by boiling over a slow fire until the soap is completely dissolved. After removing from the fire add two gallons of kerosene and beat until the oil is thoroughly mixed with the soap and water.

This stock solution is too strong for any plant and will kill the leaves and tender parts if applied to them. Before using thoroughly mix one part of the stock solution with ten to fifteen parts of water. Apply a little to the plants to be treated and watch the results. If the leaves are burned dilute the solution still more.

Black Leaf 40

This is a tobacco preparation containing 40 per cent nicotine, or the active poison in tobacco. As a remedy for plant-lice one part of "black leaf 40" is mixed with 600 to 800 parts of water and sprayed on the infested plants, care being taken to spray the aphids thoroughly. As the black leaf is very poisonous great care should be taken in handling it.

Lime-sulphur Mixture

In the case of those aphids which cause the leaves to curl, spraying in winter or early spring to kill the eggs and newly hatched lice is most effective. For this purpose the lime-sulphur mixture has proved satisfactory. This mixture may be made on the farm, but it can be purchased in a concentrated form from insecticide dealers at a cost not exceeding that of making it. The trees or shrubs to be treated should be thoroughly sprayed before the buds begin to open.

Tobacco Decoction

This is made by boiling tobacco stems or powder in water. Two pounds of the former to four gallons of the latter make a mixture sufficiently strong for general use. Do not let the mixture boil violently as this drives off some of the nicotine, thus reducing its strength.

DESCRIPTION AND LIFE HISTORY

In size and color the plant-lice vary greatly. Among the larger species the bright red Macrosiphum so common on the stems of golden-glow in late summer is very conspicuous. Contrasted with this is the small green species commonly found on the under side of rose leaves and clustered about the unopened buds.

Many aphids have two tubes near the tip of the abdomen (Fig. 23, Page 113). These are called honey tubes, and it was originally supposed that the sweetish liquid or honey dew which is discharged from the alimentary canal was discharged through them.

The mode of reproduction of plant-lice differs from that of other insects. The louse hatching from the over-winter egg and all of the individuals of several subsequent generations produce living young without the aid of the male element. This "asexual" reproduction, as it is called, usually continues until cold weather approaches. In the fall true males and females are produced. These mate and the females produce the eggs which carry the species over winter.

In some species the young of a single individual consist of both males and females, while in the case of others one set of females bear all female and another all male young.

The rate of reproduction is exceedingly rapid, a generation being produced every few days during warm weather. This rapid multiplication results in widespread damage, many times, before the presence of the lice becomes known.

NATURAL ENEMIES

Were it not for the natural enemies of plant-lice in the form of predacious and parasitic insects, fields, orchards and gardens would soon be overrun by them.

Chief among these natural enemies are the lady-beetles, two of which are shown in Figure 10, Plate II, Page 13, and Figure 15, Plate IX, Page 27, and their larvae in Figure 15, Plate II, Page 13, and Figure 23, Plate IX, Page 27.

The aphis-lion (Fig. 18, Plate IX) and its parent (Fig. 19, Plate IX), the lace-winged fly, are persistent aphid destroyers. (See pages 133 and 134.)

The larvae of many Syrphus-flies, one of which is shown in Figure 13, Plate VI, Page 21, devour large numbers of plant-lice.

(a) GREEN PEACH-APHIS

(Figs. 2, 9 and 10, Plate VIII, Page 25)

As a sugar beet pest the green peach-aphis is of little importance. However, under favorable conditions for its multiplication, it often occurs in considerable numbers on the under side of beet leaves.

NATURE OF INJURY

Injury to sugar beets is due to the withdrawing of the sap from the leaves by the aphids in feeding. This retards the growth of the plants. The presence of lice is sometimes indicated by pale green or whitish blotches on the upper side of the leaves.

As its name indicates, the green peach-aphis is found on the peach tree. It also feeds upon the plum tree. Its greatest damage is done to these trees during early summer.

METHODS OF CONTROL

Spray infested peach and plum trees with lime-sulphur mixture (See page 115) before the buds open in the spring to kill eggs and newly hatched stem-mothers. After the buds open use black leaf 40. (See page 114).

The lice should be killed on the fruit trees. After they have migrated to the beets it is practically impossible to kill them.

DESCRIPTION

The apterous or wingless lice (Fig. 9, Plate VIII, Page 25) are most plentiful. A few winged lice (Fig. 10, Plate VIII, Page 25) may be found among the wingless ones, especially during the latter part of the summer. These differ from the wingless individuals in coloring as well as form. The most distinguishing mark is the dark patch on the abdomen.

LIFE HISTORY

In early spring the eggs, which are deposited on peach or plum trees, hatch. In a few days the pinkish stem-mother, as the louse from the egg is called, becomes mature and begins depositing her young on the leaves. These young are not pink like their mother, but green, as shown in Figure 9, Plate VIII, Page 25. In due time these green lice begin giving birth to young.

The lice of this third generation very largely become winged (Fig.10, Plate VIII, Page 25). These winged lice migrate to a number of annual plants where the summer generations are produced. The list of about eighty plants upon which this louse spends the summer includes nearly every vegetable grown in the garden.

With the approach of fall the winged lice of the late summer generations return to the peach and plum trees. The first lice to return to these trees give birth to wingless females which lay eggs instead of giving birth to young. About the time these females are mature the winged males begin to arrive from the summer hosts.

After mating the females deposit several greenish eggs, which later become shining black. These eggs (Fig. 2, Plate VIII, Page 25) serve to carry the species through the winter.

(b) BLACK BEET-SEED LOUSE*

(Figs. 6 and 7, Plate III, Page 15)

The black beet-seed louse is notorious because of its injury to sugar beet seed, both in Europe and America. In this country it has been particularly destructive in some of the western states where beet seed is being grown on a commercial scale.

NATURE OF INJURY

In feeding upon beet seed plants the lice congregate in compact masses at the tip of the growing seed branches. Their feeding so exhausts the sap that the plants make very slow growth and in severe cases the infested branches die. The yield of seed is very materially reduced as a result of attack by this louse.

METHODS OF CONTROL

Hand Picking

In Europe all infested branches are collected and carried from the field, together with the lice, and destroyed. This method is hardly practicable except in the case of cheap labor and selected breeding plants.

Black Leaf 40

Spraying infested plants with black leaf 40 (See page 114), one part to 600 to 800 parts of water, will destroy the lice and not affect the quality of the seed.

Winter Spraying

Spraying the winter host with lime-sulphur mixture (See page 115) to destroy the eggs before the buds open or with black leaf 40 (See page 114) as the lice are hatching in spring is undoubtedly the most effective means of controlling this pest.

Destruction of Summer Hosts

When lice occur on wild plants during the summer these should be destroyed, together with the lice on them. The destruction of all wild host plants in the vicinity of beet seed fields, before they become infested, is to be recommended.

*There is some evidence that there may be more than one species of black louse attacking beet seed in the United States. This Bulletin discusses but one, the species damaging beet seed in Northern Colorado.

DESCRIPTION

The black beet-seed louse occurs in three forms.

Fig. 24. A Branch of *Euonymus* Species, showing Star-shaped Fruit

1. Wingless Lice

The majority of the lice during the warmer months are wingless. These wingless lice (Fig. 6, Plate III, Page 15) are a very dark, dull green. As the name implies, they are so dark as to appear black, with the exception of the legs, which are yellowish. Some of the older individuals have several white tufts on the abdomen.

2. Pupae

As the season advances many of the lice develop wing pads. These are the immature "alate" or winged lice. These pupae, as they are sometimes called, also have the white tufts on the abdomen.

3. Winged Lice

The color of the winged lice (Fig. 7, Plate III, Page 15) is similar to that of the wingless individuals except that the head and thorax (that part of the body just back of the head) are a shining black. The wings show rainbow colors when the light strikes them at the proper angle.

LIFE HISTORY

The life history of this louse is very similar to that of the green peach-aphis.

The winter is spent in the egg stage on the twigs of a shrub variously known in different parts of the country as spindle tree, burning bush, waahoo, and strawberry bush (Fig. 24, Page 118).

The first winged lice in the summer migrate to the summer hosts, which include beet seed and a variety of weeds and wild plants, poppies,

and several varieties of beans, especially the horse bean of Europe. In the fall the migrants return to the winter host, where the sexual forms mate and the eggs are produced.

2. THE TRUE BUGS

People who are not familiar with their classifications are apt to apply the word "bug" to all insects. However, strictly speaking, this name is only properly applied to those sucking insects belonging to the order *Hemiptera*. Many authors confine the term to individuals of the sub-order *Heteroptera*. Like most of the scientific names of insects, this one seems unnecessarily long and meaningless to the average reader. It is taken from two Greek words, "heteros," meaning diverse, and "petron," a wing, and was suggested by the peculiar form of the wing of these bugs.

The common stink-bug so frequently encountered on raspberries and other small fruits and the notorious chinch bug of the grain fields of the Mississippi Valley are familiar representatives of this group.

Several species attack the sugar beet, of which the false chinch bug is the most important in the arid West.

(a) FALSE CHINCH BUG

(Figs. 11 and 12, Plate VIII, Page 25)

This insect has attracted quite widespread attention because of its damage to sugar beet seed. When very numerous it has been known seriously to injure commercial sugar beets also.

NATURE OF INJURY

In feeding, the false chinch bug congregates in compact masses upon a few plants. The juice of these plants is so rapidly exhausted that they wilt and become lifeless in a very short time.

When attacking commercial beets the bugs congregate about the crowns of small plants, or on the leaves, which soon become wilted and dead. The growth of commercial beets is very much retarded and in extreme cases small beets are killed.

The growing tips of the branches of seed beets are attacked. The sap of these is soon so exhausted that they droop and die. The yield of seed is very much reduced by the feeding of this pest.

When the sap of one plant is exhausted the bugs move to others, and as they are strong fliers and voracious feeders they affect large areas in a short time.

Fields of commercial beets near waste land overgrown with peppergrass or shepherd's purse and other plants of the mustard family are quite apt to be attacked.

The odor of the blossoms of seed beets seems to attract the false chinch bug, which usually appears in seed fields about the time the plants begin to bloom. Of course the proximity of infested land to seed fields increases the infestation, at least early in the season.

METHODS OF CONTROL

Clean Culture

In the control of the false chinch bug preventive measures give more satisfactory results than the application of any remedy yet devised. As has already been intimated, this insect breeds upon various wild plants, especially shepherd's-purse and other closely related plants of the mustard family. By preventing these weeds from growing about fields, ditch banks and roadsides the multiplication of the false chinch bug in a vicinity will be materially checked.

Burning

The bugs probably spend the winter in hibernation beneath dead weeds and about the roots of grasses growing on waste land. If all unplowed land is cleaned up during the winter and early spring by burning all dead vegetation the hibernating bugs will be destroyed. If straw is spread over the ground and burned the treatment is often more effective. Many other injurious insects which spend the winter in hibernation in the same locations as the false chinch bug will be destroyed at the same time.

Hand Picking

Hand picking under certain conditions will serve to prevent the insect from injuring a crop. In catching the bugs a wide-mouthed dish of some kind should be used. Place a small quantity of water in this to which a little kerosene has been added. By suddenly slapping the infested plants the bugs can be knocked into the water and kerosene. The latter soon kills them. When the dead bugs cover the surface of the liquid skim them off. Whether or not this method of control is practicable will depend upon the value of the crop and the labor required. It is doubtful if it will pay in the case of large fields. In order that it be most effective the **work must be done during the early morning or cool days,** as in bright sunny weather the bugs are so active that they scatter upon the approach of the worker, so that but a small proportion are caught.

Sticky Shields

Sticky shields* carried through the fields have been used with some success. The same question of crop and labor values makes this a doubtful method except for small plots of very valuable crops and crops grown for experimental purposes.

Spraying

Various sprays have been employed, with rather indifferent results. Mr. F. B. Milliken* reports the killing of this pest by spraying with whale oil soap, one pound of soap to five gallons of water. According to

*F. B. Milliken, "The False Chinch Bug and Measures for Controlling It," Farmers' Bulletin No. 762, U. S. Department of Agriculture (1916).

this author the above is too strong for turnips and radishes, for which one pound of soap to ten gallons water should be used, adding one part of nicotine sulphate to 1000 parts of water.

DESCRIPTION

The Egg

The eggs, which are deposited in crevices of the ground and upon certain plants, are very small, being about $\frac{1}{64}$ of an inch long by about one-fourth as wide at the greatest diameter. They are finely ribbed lengthwise. The color is pale yellowish white, taking on an orange tinge as the young bug develops within.

The Nymph

The nymphs are slightly reddish when first hatched, becoming grayer with age. When about half grown they appear as shown in Figure 11, Plate VIII, Page 25.

The Adult

The adult (Fig. 12, Plate VIII, Page 25) is about $\frac{3}{16}$ of an inch long. The color of the head, body and legs is brownish gray, with fine dark spots over the surface. These spots are especially prominent on the legs. The wings are whitish. The color of the body showing through them gives them a grayish appearance.

LIFE HISTORY

The number of broods produced annually will depend upon the latitude and general weather conditions prevailing. There are probably four or five in the latitude of Denver.

According to the author already quoted,* the late fall and early spring broods deposit their eggs in cracks in the soil surface or in pulverized soil. During the warmer months the eggs are thrust among the clustered parts of plants such as the flower heads of some weeds** and the glumes of the strong scented stink-grass or love-grass.

When first hatched the young feed upon weeds almost exclusively, especially the shepherd's-purse, peppergrass and pennycress.

At maturity the adults scatter to other plants. It is at this time that beet seed fields become infested.

The adults of the last generation in the fall spend the winter in hibernation.

NATURAL ENEMIES

Very little seems to be known of the natural enemies of this bug. The writer has observed many adults containing the maggots of a small two-winged fly.

Many bugs were killed by a fungous disease in breeding cages, but no noticeable effect of this malady was observed in the field.

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*F. B. Milliken, "The False Chinch Bug and Measures for Controlling It," Farmers' Bulletin No. 762, U. S. Department of Agriculture (1916).

**_Gaillardia pulchella_ Foug. _Mollugo verticillata_ L.

(b) TARNISHED PLANT-BUG

The tarnished plant-bug is one of the most common of the true bugs. It is found everywhere in North America from Mexico to Canada and feeds upon almost any plant, either cultivated or wild. This bug often attacks sugar beets.

NATURE OF INJURY

Only when tarnished plant bugs are abundant are there any visible effects of their feeding. During the latter part of the season, however, they often attack the young leaves at the center of the beet crown in such numbers that the tips of these leaves wilt and finally become brown and dry. Frequently the injured beets begin to make growth in the axil of the outer leaves. This gives the beet top a bushy appearance.

METHODS OF CONTROL

Sugar beets are rarely injured to the extent where remedial measures are profitably applied.

Clean Culture

Since the tarnished plant-bug spends the winter in hibernation under the trash about fields, ditch banks and fence rows and breeds on the weeds growing in these places during the early part of the season, cleaning up all waste land by burning during winter or early spring will destroy many of them. By preventing the weeds from growing about fields the bugs are not so apt to be attracted to them as when these wild plants are plentiful in and about them.

Kerosene Emulsion

In the case of small garden plots kerosene emulsion (Page 114) is probably the best remedy where the nature of the crop attacked is such that it can be used.

Dr. F. H. Chittenden* states that where insecticides are used they should be applied early in the morning while the dew is still on the plants and the bugs are not very active.

Hand Picking

Hand picking may be resorted to where the areas covered by the attack are small. It is obvious that this method is not suited to large fields.

DESCRIPTION

The Egg

The eggs, which are about $\frac{1}{13}$ of an inch long, are oval, several times as long as thick and flared at one end so as to be somewhat bottle-shaped. The color is a pale yellow.

The Nymph

The nymphs pass through four stages in the course of their development. In the first stage they are about $\frac{1}{20}$ of an inch in length and of a yellowish or yellowish green color.

*"A Brief Account of the Principal Insect Enemies of the Sugar Beet," Bulletin No. 43, Division of Entomology, U. S. Department of Agriculture (1903).

The second stage differs from the first in that the nymphs are about twice as large and have two pairs of dark spots on the thorax.

These spots become more distinct in the third stage and the wings are represented by two small pads on the back margin of the thorax.

In the fourth stage the wing pads reach nearly half way down the back and the four dark spots become quite prominent.

The Adult

The adults are nearly one quarter of an inch in length. The color ranges from a greenish to a brassy brown. The markings are quite variable. Some individuals are quite prominently marked with black, yellow and red, while others are much more modestly colored, greenish brown predominating.

LIFE HISTORY

The adults, as already mentioned, as well as some nymphs in the third and fourth stages, hibernate under any convenient trash or under stones, boards and leaves about fields and waste land.

The adults emerge during the first warm days of spring, and egg-laying begins soon after emergence. Little seems to be known about the place where the eggs are deposited. In all probability, they are placed within the stems of the plants upon which the adults feed. In the latitude of Northern Colorado the eggs of the first generation are deposited about the last of April and early May.

About a month is required for the development of a single generation. Therefore, there are probably two or three generations each season.

The generations overlap to such an extent that nymphs of all stages and adults can be found feeding together during the entire summer.

NATURAL ENEMIES

Very little is known regarding the natural enemies of this insect. In all probability it is held in check by predacious and parasitic insects and fungous diseases similar to those attacking the false chinch bug.

3. LEAF-HOPPERS

With the exception of the aphids, leaf-hoppers probably exceed in number of individuals all other families of sucking insects attacking cultivated crops.

Although most leaf-hoppers feed upon grasses, often occurring in meadows in such numbers that it has been estimated that from one-fourth to one-half of all the grass growing annually is destroyed by them, several species seriously damage field crops, vegetables, fruits and shrubs.

The small cream colored rose leaf-hopper which causes the whitish blotches on the leaves of cultivated and wild roses is familiar to nearly every one and will serve as a typical example of this group of insects, several species of which attack the sugar beet.

(a) SUGAR BEET LEAF-HOPPER

(Figs. 5, 6 and 7, Plate VIII, Page 25)

Few insects attacking the sugar beet cause as large annual losses as this minute leaf-hopper. Fortunately this pest has not appeared to any

damaging extent in the territory in which The Great Western Sugar Company operates.

Its association with the disease known as "curly-top," (Fig. 5, Plate VIII, Page 25), or more locally as "blight," "western blight" or "whiskered beets" (Fig. 7, Page 60), has long been known, but just how its feeding produces the malady is not so well known.

Fig. 25. Sugar Beet showing characteristic Curling of Leaves caused by Curly-top (After Harry B. Shaw, Bulletin No. 181, U. S. Bureau of Plant Industry)

NATURE OF INJURY

Indications of Injury

The symptoms of injury by this leaf-hopper are to be found upon all parts of the plant. The first to appear is usually an inward curling of the inner leaves. This is associated with a distortion and enlargement of the veins of the leaf (Fig. 5, Plate VIII, Page 25). In severe cases the veins are covered with nipple-like protuberances. As the disease advances the whole plant becomes affected. The leaves become badly crumpled (Fig. 25, Page 124), the stunted roots develop an abnormally large number of fibrous rootlets from the root seams (Fig. 7, Page 60), and the root itself becomes darkened, especially where the rings of fibrovascular bundles show in cross sections (Fig. 26, Page 125). The crown of the beet will often be covered with a sweet gummy substance which exudes from the beet.

How the Disease is Transmitted

In some way not at present thoroughly understood, certain so called virulent leaf-hoppers have the power of producing curly-top in healthy beets. A single individual which possesses this power will infect a healthy plant if confined upon it for five minutes.*

*E. D. Ball, "The Beet Leafhopper and the Curly-leaf Disease That It Transmits," Bulletin No. 155, Utah Agricultural College (1917).

Normal individuals do not have the power to cause the disease. It has been demonstrated quite recently that before a sugar beet leaf-hopper can transmit curly-top it must itself become inoculated by feeding upon a diseased plant.

There seem to be many points in common between the carrying of curly-top by these leaf-hoppers and the relation existing between certain mosquitoes and malaria fever transmission. The micro-organism which is now supposed to be the real cause of the disease must be taken up by the leaf-hoppers while feeding on a diseased plant and then transmitted to healthy plants during the process of feeding upon them.

Fig. 26. Cross Section of Sugar Beet, showing Darkening of Rings caused by Curly-top (After C. O. Townsend, Bulletin No. 122, U. S. Bureau of Plant Industry)

Investigations, the results of which have just been published,* emphasize the importance of clean culture as a possible means of controlling this insect.

These investigations show that without a doubt the wild host plants of the beet leaf-hopper become diseased and that when fed upon by non-virulent leaf-hoppers, these insects become inoculated and can and do transmit the disease to healthy sugar beets. The plant experimented with was a common mallow.

METHODS OF CONTROL

There is very little to be said regarding the control of this insect. In fact there is no known method by which curly-top can be prevented.

The practicing of clean culture and the working and burning over of all possible hibernating places is always to be recommended, but even this is not sufficient. Until more is known of the insect and its association with curly-top we cannot hope to be able satisfactorily to prevent the damage it causes. There are cases on record where early planting prevented injury. This does not seem to be a sure remedy in all localities, however.

*"Wild Vegetation as a Source of Curly-top Infections of Sugar Beets," Boniquit and Slake, Journal of Economic Entomology, Vol. 10, No. 4 (1917).

DESCRIPTION

The Egg

The eggs, which are pearly white, are deposited in the tender stems of beet leaves. Late in the season the elliptical scars caused by the punctures made in depositing the eggs are sometimes very numerous.

The Nymph

The young leaf-hoppers or nymphs (Fig. 6, Plate VIII, Page 25) are very minute, active little fellows of a creamy white color. They are so small and so easily disturbed that they are found only by making very careful search for them.

The Adult

The fully matured sugar beet leaf-hopper (Fig. 7, Plate VIII, Page 25) is about one-eighth of an inch long, and with the exception of the eyes, is of a light creamy white color. They are so exceedingly small and active that they are very difficult to observe in the field except as they fly from plant to plant.

LIFE HISTORY

The following summary of the life history and habits is taken from U. S. Department of Agriculture Bulletin No. 181, by Harry B. Shaw:

"The beet leaf-hopper is single brooded and begins to deposit its tiny, white eggs in the stems and midribs of beet leaves from about the end of June—the time doubtless varying somewhat with the locality and local climatic conditions—until the end of August. Probably the majority of the eggs are deposited by the middle of July. The nymphs begin to appear about the second week in July, and the writer has observed their appearance in considerable numbers in Idaho as late as the end of August. Slit-like scars are produced on the beet stems where the eggs have been deposited; sometimes these ovipository scars are very numerous and conspicuous. The egg stage appears to last about fifteen days, and the young insects reach the adult stage in about twenty days more. These adults hibernate and resume their activity the following spring. In Utah and Idaho they have been seen on weeds in May and on beets near the end of May or early in June. The greater portion of the nymph stage appears to be spent among the inner leaves and petioles of the plant, where the egg is hatched, and as the insect approaches the adult stage it gradually works outward.

"The beet leaf-hopper is an exceedingly active insect; its favorite mode of locomotion is by hops of lightning-like rapidity. The range of its leaps seems to be about 18 inches. The adult while on beets uses its wings but little. In common with several closely related species it is a true sucking insect; it is provided with powerful head parts and a stout bill. The latter when not in use is tucked snugly against the under side of the body."

(b) CLOVER LEAF-HOPPER

(Fig. 8, Plate VIII, Page 25)

The clover leaf-hopper is frequently encountered in quite large numbers in beet fields and is often mistaken for the sugar beet leaf-hopper just discussed. It can be easily distinguished from it, however, by its

more robust form, slightly larger size and darker color. The two dark spots on the head between the eyes serve to distinguish it from many other small, grayish species with which it is often associated in clover and alfalfa fields, where its greatest damage is done.

NATURE OF INJURY

Fields of sugar beets where this crop has followed alfalfa have been seriously damaged in the early part of the season while the beets were still small. The injury is most severe during dry, hot weather.

The leaves of sugar beets attacked by this insect are covered with light, grayish areas as a result of the punctures and irritation caused in feeding. If the weather is dry and warm the plants show a very striking lack of thrift and make very slow growth. An examination of such beets will reveal the leaf-hoppers on the under side of the leaves, or during bright sunny days they will be seen flying ahead of one walking through the field.

METHODS OF CONTROL

Clean Culture

Keeping waste land free of rubbish by burning all dead vegetation during the fall will prevent the adults from hibernating about fields. Burning during the winter or early spring will destroy the hibernating adults.

DESCRIPTION

The Egg

The eggs, which are white and very small, are placed in slits in the host plants. These slits are made with the saw-like ovipositor of the female.

The Nymph

The young or nymphs resemble the adults in form but lack the wings of the latter. Their color is a creamy white with darker spots and bands.

The Adult

The adult leaf-hopper (Fig. 8, Plate VIII, Page 25) is of a light grayish color with dark markings. The face is marked with short, dark stripes and just between the eyes on the top of the head are two dark spots.

LIFE HISTORY

The hibernating female places her eggs in the stems of plants in early spring. These hatch in from five to twelve days during the warmer months.

The number of generations varies with the latitude and general weather conditions. In the latitude of Denver there are at least two and probably three each year.

The nymph stage lasts from 20 to 30 days, with an average of about 25 days. The last generation hibernates during the winter at the base of clumps of grass and about the roots of weeds or under rubbish lying about fields and waste lands.

In the warmer sections of the Southern states the adults are more or less active during the entire year, and in the extreme South they do not hibernate at all.

(c) EUTETTIX STROBI FITCH

(Figs. 1, 3 and 4, Plate VIII, Page 25)

This bright colored leaf-hopper (Fig. 4, Plate VIII, Page 25) is the cause of the deep purple blotches (Fig. 1, Plate VIII, Page 25) so often seen on the leaves of lamb's-quarters and sugar beets during spring and summer.

It is not of interest to beet growers because of any damage it does to the crop but because of the widespread attention which the discoloration of the leaves, caused by its feeding, attracts.

During late spring and early summer and again during late summer the nymphs (Fig. 3, Plate VIII, Page 25) may be found on the under side of the leaves, resting on the colored spots. Their color harmonizes so completely with these spots that they are easily overlooked.

The adults (Fig. 4, Plate VIII, Page 25) are very prettily marked with shades of tan and brown, and measure about one-fourth of an inch in length. The dark saddle across the center of the wings is especially prominent. This is one of our most brightly colored and attractive leaf-hoppers. There appear to be two broods of this insect annually, the adults appearing in June and August.

CHAPTER IV

BENEFICIAL INSECTS

So much is written about the injurious insects in bulletins and farm papers that we are apt to look upon all insects as the arch-enemies of mankind. However, if we study those about us carefully we are soon astonished at the number of friends we have among them, friends whose whole existence is one constant warfare against our enemies. It is not enough that we learn to recognize enemies alone; we should know our friends as well and do all we can to encourage and protect them.

In the preceding pages frequent mention has been made of beneficial insects in connection with the particular injurious species which they help to control. However, out of justice to our insect friends and ourselves it is only right that we devote a few pages to a general discussion of this large but little appreciated group.

Every order of insects contains forms which feed upon other forms of insect life. However, these friendly species are in some cases so minute that they are overlooked, or their work of ridding our fields of noxious insects is carried on so quietly that their presence is not apparent. Still others so resemble some of the injurious species that their real mission is not suspected. Instead they are blamed for the damage they are really helping to prevent. Many times friends are taken for foes because in searching for the real culprits they are forced to frequent the damaged crop. Unless we are familiar with these insects they often share the fate of the spy who, in order to hide his identity more completely, appears in the role of an enemy.

Beneficial insects are spoken of as either predacious or parasitic. Owing to the fact that, in habits, these two groups are not clearly defined, but merge one into the other, it is very difficult to give a definition of the terms predacious and parasitic which is wholly satisfactory.

In a general way insects which wander about in search of the insects upon which they feed are spoken of as being predacious. Insects of this class require many hosts or victims for their maintenance.

Insects which pass the entire larval stage within the body of a single host, or attached to a single host from which they draw their nourishment, are said to be parasitic.

Parasites gain entrance to the host in many ways. The adult parasite of some species stings its eggs into the body of the host, using for this purpose a sharp organ called the ovipositor. This is usually located at the tip of the abdomen or near it on the underside of the body. Other parasites fasten their eggs onto the surface of the host's body. When the young parasite emerges from the egg it burrows into the host. In other cases the young parasite remains on the outside with only a small portion of its body, including the head, buried in the host.

The larvae of certain flies are deposited upon the host and immediately proceed to enter its body through natural openings or by burrowing through some tender tissue.

These parasitic larvae feed upon the blood of the host insect. The host in many cases remains alive and functions naturally until the parasite is fully mature. In the case of some caterpillars the parasite does not emerge until after the change to the pupa has taken place.

Some parasites live only within closely related insects. Thus certain kinds are parasitic upon cutworms only, others upon grasshoppers and related insects, and still others upon the eggs of certain insects.

Since these parasites are dependent upon certain hosts for their existence their numbers rise and fall with the increase and decrease of their hosts. This is why some noxious insects become so numerous at times. A scarcity of these insects is followed by a scarcity of their parasites. When the parasites become very few and favorable conditions exist for the multiplication of a particular insect it often increases so rapidly as to do much damage before the parasites again get the upper hand.

A. PREDACIOUS INSECTS

1. GROUND BEETLES

(Figs. 1, 2, 3, 20, 21 and 22, Plate IX, Page 27)

The popular name, "ground beetle," has been applied to these beetles because they are most frequently encountered running rapidly over the ground or lurking under stones or other objects lying on its surface.

The majority of these beetles are shining black. However, some are bright metallic green, dark blue, brown or even spotted. Their legs are long and slender and their movements rapid.

Most of the species are predacious, feeding upon other insects which they capture either by pouncing upon them or by chase. Several species feed upon vegetable matter, but their depredations are rarely, if ever, of great economic importance.

The larvae of ground beetles frequent the same places as the adults, and, like them, are predacious. Figure 1, Plate IX, Page 27 will serve as a typical example of ground beetle larvae. Figure 3, Plate IX, Page 27 represents a very common, black ground beetle, while Figures 20, 21 and 22, Plate IX, Page 27 represent the larva, pupa and adult of a species already mentioned in connection with the natural control of grasshoppers.

(a) FIERY HUNTER

(Figs. 1 and 2, Plate IX, Page 27)

The fiery hunter is one of our largest ground beetles and can be recognized by the copper colored or golden spots on the wing covers. This beetle (Fig. 2, Plate IX, Page 27) and its larva (Fig. 1, Plate IX, Page 27) are particularly fond of caterpillars. By some authors it is known as the "caterpillar killer." Many a cutworm has fallen a prey to these beetles.

(b) BOMBARDIER-BEETLES

The members of one group of ground beetles are provided with a sack of very volatile fluid at the tip of the abdomen. When pursued, this fluid is ejected with a loud popping sound and as it comes in contact with the air it is reduced to a gas which appears like a tiny puff of smoke. The sharp report accompanied by the puff of smoke-like gas suggested the name "bombardier-beetles," by which these beetles are known.

2. TIGER-BEETLES

(Figs. 5, 6 and 7, Plate IX, Page 27)

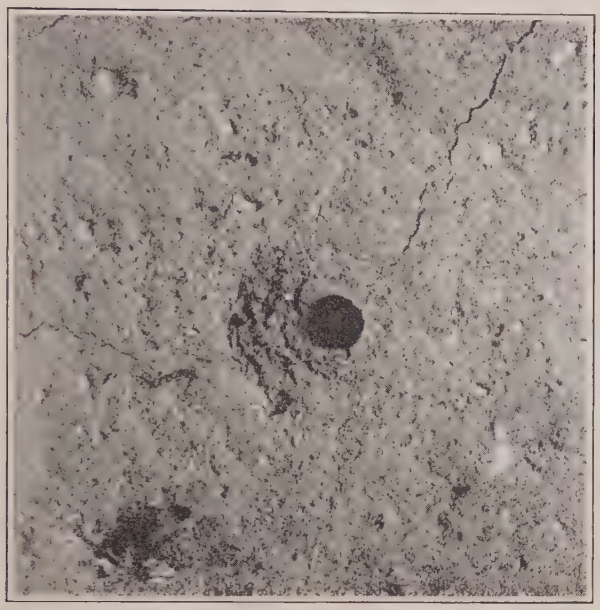

Fig. 27. Entrance to Burrow of Tiger-beetle Larva. There is never any soil at the entrance to these burrows.

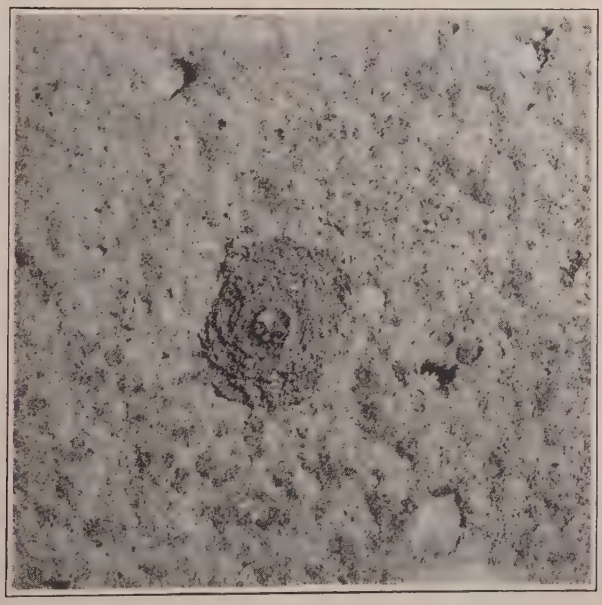

Fig. 28. Same Burrow as shown in Figure 27, with head of larva resting on level with the surface, ready to seize a victim.

The tiger-beetles are common objects about the borders of fields or on beaten pathways and roadsides. They are lovers of sunshine and frequent exposed positions.

The tiger-beetles are the most agile of all beetles, being equally at home on the ground, where they run with amazing rapidity, or on the wing. When approached they take flight, fly a short distance, and invariably alight facing the intruder.

The larvae and adults are predacious, feeding entirely upon other insects. One author states that the only thing in common between these beetles and their young is their eagerness for prey.

The larva (Fig. 5, Plate IX, Page 27) is an uncouth creature and spends its entire existence in a perpendicular burrow (Fig. 27, Page 131) in the hard ground of some path or roadside. During the day it lies with its head just at the surface of the ground (Fig. 28, Page 131), its jaws open like a steel trap, waiting

for some unfortunate insect to pass near. When one comes within reach the jaws snap shut and the victim is drawn into the burrow and devoured.

In order to prevent some stronger insect from dragging the young tiger-beetle from its burrow, nature has provided it with a peculiar anchor in the form of a hump on the fifth segment of its abdomen. This hump is armed with several curved hooks which fasten into the walls of the burrow, thus making it possible for the larva to withstand the pull of a powerful victim.

The adults (Figs. 6 and 7, Plate IX, Page 27) are usually a metallic green or bronze banded with light markings, from which comes the name "tiger-beetle." However, some are black, while others are light, in harmony with the color of the sand on which they live.

3. LADY-BEETLES OR LADY-BUGS

(Figs. 14, 15, 23 and 24, Plate IX, Page 27; Figs. 10 and 15, Plate II, Page 13; Fig. 14, Plate VII, Page 23)

The lady-beetles, or lady-bugs, as they are commonly called, are among the best known and most important predacious insects.

Both the adults and larvae feed upon small, soft bodied insects and insect eggs.

These beetles have the peculiar habit of congregating in very large numbers in the fall of the year just before going into hibernation. At such times they can be scooped up by the quart as they cluster about the bases of trees and shrubs or under stones, in layers many deep. Such a congregation of the species discussed below occurred at the very top of one of the highest mountain peaks near the city of Denver in 1916.

Hippodamia convergens (Fig. 15, Plate IX, Page 27) is the commonest of all species. This, together with several others, is especially noted for the numbers of plant-lice which it destroys. The larva (Fig. 23, Plate IX, Page 27) is a common object among colonies of plant-lice, where the pupa (Fig. 24, Plate IX, Page 27) is also often encountered fastened to a twig or leaf. Other species are especially useful for their work in orchards, where they devour scale insects which would otherwise injure the trees and fruit. Figure 10, Plate II, Page 13 shows a lady-beetle which feeds upon sugar beet root-lice. Figure 15, Plate II, Page 13 shows the larva, and Figure 14, Plate VII, Page 23, the pupa, of this same beetle.

The eggs of lady-beetles vary with the species, as does the place selected for depositing them. Those of our common forms resemble the eggs of the Colorado potato-beetle, but are smaller. They are deposited in clusters, the eggs standing on end. A cluster of the eggs of *Hippodamia convergens* is shown in Figure 14, Plate IX, Page 27.

4. TRUE BUGS

(Fig. 14, Plate II, Page 13)

The majority of the true bugs are vegetable feeders, and pests of the first magnitude. However, several families contain species which are predacious, feeding upon the blood of other insects or the higher animals, which is sucked up through their strong, jointed beaks.

(a) ASSASSIN-BUGS

The members of this family are so pre-eminently predacious that they are known as the assassin-bugs. Their mode of attack is truly that of the assassin. Approaching their prey by stealth or lying in wait for it, they pounce upon their victims and pierce them, oftentimes in the back, with their beaks and proceed to drink up their life blood.

One noted member of this family feeds upon bedbugs and is known as the masked bedbug hunter. This insect infests houses where its prey is found.

(b) AMBUSH-BUGS

The bugs of this family are called ambush-bugs because of their habit of lying concealed in flowers, especially those of thistle and golden-rod, patiently waiting for some nectar loving insect to visit their ambush. The unlucky visitor is grasped with the much enlarged fore legs of the ambush-bug and impaled on its strong beak.

The common species of this family are yellowish or greenish, marked with dark bands and spots. The abdomen is broadened behind, concave on top and very convex below. The forward pair of legs is very much enlarged and armed with heavy claws with which the bug's prey is held.

(c) STINK-BUGS

(Figs. 8 to 13, Plate IX, Page 27)

The members of the stink-bug family are furnished with glands which secrete a very ill-smelling fluid which escapes through two openings on the under side of the body.

While most of these bugs feed upon vegetables, some being noted pests, several species are predacious.

The pictured soldier-bug (Figs. 12 and 13, Plate IX, Page 27) is noted as a destroyer of potato-beetles, and also feeds upon alkali-beetle larvae. The eggs (Fig. 8, Plate IX, Page 27, natural size, and Fig. 9, Plate IX, Page 27, enlarged) are placed on the leaves of potatoes and other plants where the insects fed upon by the young are found.

When first hatched the young are reddish, as shown in Figure 11, Plate IX, Page 27. The half-grown nymphs appear as in Figure 10, Plate IX, Page 27. The adults are of two colors, as shown in the figures.

5. LACE-WINGED FLIES

(Figs. 16, 17, 18 and 19, Plate IX, Page 27)

The delicate, green, lace-winged fly or golden-eyes (Fig. 19, Plate IX, Page 27), as it is frequently called, is a familiar object flitting about in the cool of dense foliage, especially where aphids or other small, soft bodied insects are numerous.

The eggs (Fig. 16, Plate IX, Page 27) are always attached to the surface of a leaf or other object by a hair-like stalk about one-half inch long. One author* states that this is nature's way of protecting the unhatched eggs from the newly hatched larvae, which are so exceedingly voracious that even their own unhatched brothers and sisters are not safe when other food is not available.

*Comstock, "Manual of Insects," page 181.

The larvae (Fig. 18, Plate IX, Page 27) are common among aphid colonies. When first hatched they devour these soft bodied insects at the rate of four or five a day and at the rate of twenty or more a day when fully grown. Because of the numbers of plant-lice they devour, these spindle-shaped larvae are called aphis-lions.

In feeding, the aphis-lion seizes its prey in its long jaws, which are so formed that each pair makes a tube through which the body contents of the aphid are sucked up.

During its existence as a larva the lace-winged fly probably consumes from 300 to 400 plant lice.*

Many other small insects are eaten besides aphids. In the article referred to in the preceding paragraph, the author lists ten insects besides several species of plant-lice as hosts of the green lace-wing of California. Among these are mites, leaf-hoppers, scale insects, mealy-bugs and psyllids.

When the larvae are fully grown they spin a white globular cocoon (Fig. 17, Plate IX, Page 27), within which the pupal stage is spent. The adult escapes by gnawing the end of the cocoon partially off and pushing this up as shown in the figure.

As there are several generations of the lace-winged fly each season their importance as destroyers of injurious insects is difficult to estimate.

6. WASPS

(a) DIGGER-WASPS

(Figs. 16, 17 and 18, Plate VI, Page 21)

We are so accustomed to considering wasps as creatures of quickly aroused temper who resent any trespassing in the vicinity of their nests by stinging the intruder, that many an innocent and beneficial member of the wasp tribe is summarily put to death and as a result many a crop pest continues its work of devastation.

There are fourteen families of digger-wasps in America north of Mexico. Many of the members of these render invaluable service to the farmer and gardener by destroying the insects feeding upon his crops. In habits many of these represent a class intermediate between the true predators, such as the ground beetles, and the true parasites, which will be discussed later.

(a-1) FAMILY SCOLIIDAE

One member of this family, *Tiphia inornata*, which has been previously mentioned, burrows into the ground in search of white grubs, upon which it lays its eggs and upon which the larvae are parasitic.

These wasps are shining black and about three-fifths of an inch long.

(a-2) SPIDER-WASPS

Most of the members of this family dig burrows in the ground which are stocked with spiders upon which the young wasps feed. A few species, however, build cells of mud which are fastened under stones and in other secluded places.

(a-3) THREAD-WAISTED WASPS

The wasps of this family can be distinguished from those of the preceding ones by the long slender first segment of the body. The peculiar

*V. L. Wildermuth, "California Green Lacewing Fly," Journal of Agricultural Research, Vol. VI, No. 14 (1916).

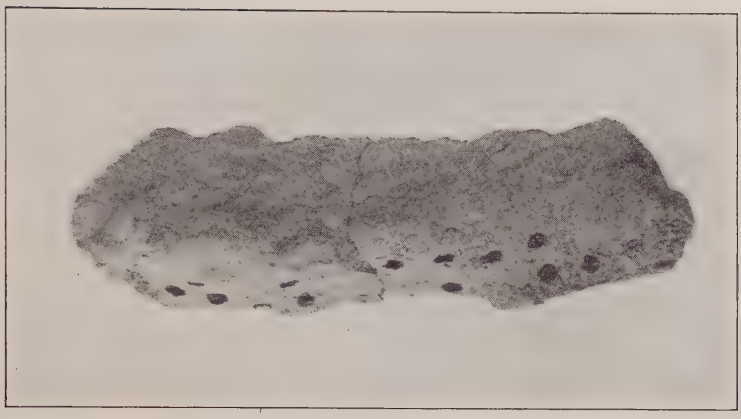

Fig. 29. Nest of a Mud-dauber taken from Rafter of an Out-building

development of this joint suggested the name "thread-waisted wasps" by which they are commonly known.

Many of these species build large many celled nests of mud on the beams of outbuildings and about farm machinery stored under implement sheds (Fig. 29, Page 135).

The cells of these nests are provisioned with spiders and caterpillars, upon which the young wasps feed.

After dry spells these wasps are common objects about mud puddles near wells or after showers, where they secure the mud required in the construction of their nests.

(b) SOLITARY WASPS

(Fig. 15, Plate VI, Page 20)

These insects, many species of which resemble the fiery tempered yellow jackets, are peculiarly subject to persecution because of this resemblance.

Some of the members of this family are masons, building their nests of mud; some are miners, digging tunnels in the earth in which their young pass through the stages of their development; and still others are carpenters, cutting out tubular nests in wood, and partitioning these off into cells with mud.

One species (Fig. 15, Plate VI, Page 21) has already been mentioned in connection with the sugar beet webworm (See page 44), and its burrow figured on page 78 (Fig. 14).

Another species builds a jug-shaped nest, which is attached to the stem of some plant, and provisions it with small caterpillars.

B. PARASITIC INSECTS

While the predacious insects do much to keep down the enemies of cultivated crops their work is not so effective as that of the true parasites, such as the Ichneumon-flies, Braconids, and Chalcis-flies.

1. ICHNEUMON-FLIES

(Fig. 5, Plate I, Page 11; Fig. 7, Plate V, Page 19; Figs. 9 and 10, Plate VI, Page 21)

Many times when our fields are overrun by a pest we wish that by some magical power we could destroy it and save our crops. Sometimes these pests do disappear as if by magic. Many times we little suspect that the small to medium sized, wasp-like insects, which we observe hovering over the field, are the friends that stood by us in our hour of need and wiped out our enemies in an incredibly short time.

The Ichneumon-flies belong to the same order of insects as the digger-wasps, already discussed.

These flies have long slender bodies. That of the female is often armed with a long hair-like ovipositor (Fig 7, Plate V, Page 19). This is composed of three parts. The central one is a tube through which the eggs pass, while the two outer ones are the sheath which protects the ovipositor proper. When the insect is alive the three parts are held close together and appear as a single hair-like organ.

The name "Ichneumon" was suggested by a fancied resemblance to the Ichneumon of Africa, which is a mammal belonging to the same family as the mink and weasel.

Mention has already been made of two Ichneumon-flies. Figure 5, Plate I, Page 11 is parasitic upon caterpillars and was reared from the western army cutworm. Figures 9 and 10, Plate VI, Page 21 represent a species which destroys the alfalfa looper.

2. BRACONIDS

(Figs. 6 and 7, Plate I Page 11; Fig. 14, Plate V, Page 19)

Closely related to the Ichneumon-flies is a group known as the Braconids. The members of this family are small or minute insects.

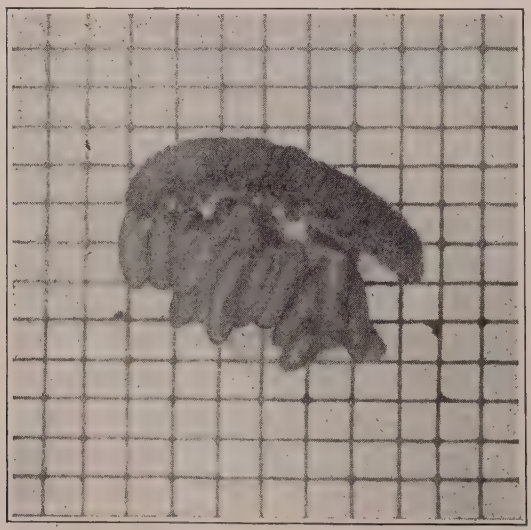

Fig. 30. A Cabbage-worm killed by the Larvae of a Braconid, the Cocoons of which are fastened to the Window-screen near it (Enlarged)

Frequently dead caterpillars are observed covered with small silken cocoons, or with a mass of these cocoons fastened to some object near them (Fig. 30, Page 136). These caterpillars have been killed by the larvae of some Braconid which have gnawed their way out of the worm and spun cocoons in which to complete their own development.

One of the most interesting forms of this family belongs to the genus *Aphidus*. These minute parasites live within the bodies of aphids. When mature the parasite escapes through a hole which it

gnaws in its dead host. If a colony of aphids is examined, especially in the latter part of the season, many brown and much inflated individuals will be observed. These are dead, and if no hole is to be seen on their backs they harbor one of these little parasites. Whole colonies of plant lice are often wiped out by these little insects.

Figure 6, Plate I, Page 11 represents a Braconid which is parasitic upon cutworms. Figure 7, Plate II, Page 11 represents a cocoon of this same species.

Figure 14, Plate V, Page 19 represents another Braconid which was reared from a sugar beet webworm cocoon.

3. CHALCIS-FLIES

(Fig. 8, Plate I, Page 11; Fig. 4, Plate IX, Page 27)

The Chalcis-flies are among the smallest parasitic *Hymenoptera*. Some species are not over one-hundreth of an inch long. They are usually black with strong metallic reflections. Some appear quite green, while others are yellow. These flies can be recognized by the lack of veins in the wings (Fig. 8, Plate I, Page 11). This Chalcis-fly, as already stated, is parasitic upon cutworms. (See page 44, and Figure 4, Plate IX, Page 27).

The greater part of the parasites of small insects belong to this family. Some are parasitic upon scale insects. One species is the most effective natural check on the cabbage-worm.

Some Chalcis-flies are parasitic within the eggs of other insects.

APPENDIX

Containing an alphabetical list of the popular names of insects and plants discussed in this Bulletin, together with their scientific classification or name, and text and illustration reference

A—INSECTS

Popular Name	Scientific Classification or Name	Text Reference	Illustration Reference	
		Page	Figure	Page
Alfalfa Cutworm		41		
(See Western Army Cutworm)				
Alfalfa Looper	*Autographa gramma californica* Speyer	8, 81–84, 136	5, 6, 7, 8	21
(1) Alfalfa Webworm	*Loxostege commixtalis* Walker*	7, 84, 85	1, 2, 3, 4	21
Alkali-beetle or Alkali-bug		7, 8, 29, 89, 90, 92, 133		
(See Larger Sugar Beet Leaf-beetle or Alkali-beetle)				
Amara, Egg-eating				
(See Egg-eating Amara)				
Ambush-bug	Family *Phymatidae*	133		
Aphids or Plant-lice	Family *Aphididae*	3, 111–116, 123, 134, 137	20, 21 23	112 113
(See also Plant-lice)				
Aphis-lion	Family *Chrysopidae*	26, 116, 133, 134	18	27
Ash-gray Blister-beetle	*Macrobasis unicolor* Kby	98	9	23
(See Blister-beetle)				
Assassin-bug	Family *Reduviidae*	133		
Banded Flea-beetle	*Systena taeniata* Say	92, 93	2	17
Bedbug	*Acanthia lectularia*	133		
Beet or Spinach Leaf-miner	*Pegomyia vicina* Lentn	110, 111	1, 2, 3, 4, 5	15
Beetles, Leaf-eating				
(See Leaf-beetles)				
Black Beet-seed Louse	*Aphis euonymi* Fab	117–119	6, 7	15
Black Blister-beetle	*Epicauta pennsylvanica* DeG	98	8	23
(See Blister-beetle)				
Black Carrion-beetle	*Silpha atrata* L	94		
Blister-beetle	Family *Meloidae*	96–98, 106	8, 9, 12, 13	23
Bombardier-beetle	Family *Carabidae*, Genus *Brachinus*	130		
Braconids	Family *Braconidae*	3, 43, 77, 135, 136, 137		

*Determined by August Busch.

APPENDIX—Continued

	Popular Name	Scientific Classification or Name	Text Reference	Illustration Reference	
			Page	Figure	Page
	Braconid parasite of Cabbage-worm	*Microgaster* Sp.	136	30	136
(2)	Braconid parasite of Cutworms	*Microgaster* Sp.	43, 137	6, 7	11
(3)	Braconid reared from Sugar Beet Webworm pupa	*Mesochrus agilis* Cress.	77, 137	14	19
	Cabbage-worm	*Pieris rapae* (larva of)	136–137		
	California Devastating Locust	*Melanoplus devastator* Scudd	100		
	Carrion-beetle, Black (See Black Carrion-beetle)				
	Carrion-beetle, Spinach (See Spinach Carrion-beetle)				
	Caterpillar-killer (See Fiery Hunter)		130		
	Caterpillars, Leaf-eating		67		
	See: Alfalfa Looper Alfalfa Webworm Sugar Beet Webworm True Army Worm Yellow-bear Caterpillar Zebra Caterpillar				
	Chalcis-fly	Family *Chalcididae*	3, 43, 44, 135, 137		
(4)	Chalcis-fly parasite of Cutworms	*Berecyntus bakeri bakeri* Howard*	44	8	11
				4	27
	Chinch Bug, False (See False Chinch Bug)				
	Click-beetle (See Wireworms)	Family *Elateridae*	52, 53, 54	16, 17	11
(5)	Click-beetle common in Northern Colorado (larva of)	*Hemicrepidius memnonius* Herbst†	54	13, 14, 18	11
	Clover Leaf-hopper	*Agallia sanguinolenta* Prov.	126–128	8	25
	Colorado Potato-beetle	*Doryphora decemlineata*	89, 132		
	Corn Root-louse	*Aphis maidi-radicis* Forbes	38		
	Corn Root-worm	*Diabrotica* Species	31, 38		
	Crickets (See Field Crickets)				

*Determined by A. A. Gerault. †Determined by J. A. Hyslop.

APPENDIX—Continued

	Popular Name	Scientific Classification or Name	Text Reference	Illustration Reference	
			Page	Figure	Page
	Cutworms		3, 4, 5, 38–48, 87, 130, 137		
	See: Pale Western Cutworm				
	Variegated Cutworm				
	Western Army Cutworm				
	Differential Hopper	*Melanoplus differentialis* Uhler	100	12, 13	17
	Digger-wasp	Superfamily *Sphecina*	43, 44, 45, 134, 136		
(6)	Digger-wasp enemy of Cutworms	*Spex luctuosa* Snw.*	44, 45	16, 17, 18	21
	Eel-worm		38, 59, 64		
	(See Root-knot Nematode or Gallworm)				
	Egg-eating Amara	*Amara obesa* Say	106	20, 21, 22	27
				16	106
	False Chinch Bug	*Nysius ericae* Schill	6, 29, 119–121, 123	11, 12	25
	Field Crickets	Family *Gryllidae*	3, 67, 109, 110	7	17
	Fiery Hunter	*Calosoma calidum* Fab	130	1, 2	27
	Flea-beetles	Family *Chrysomelidae*	7, 29, 91–93, 96		
	See: Banded Flea-beetle				
	Potato Flea-beetle				
	Three-spotted Flea-beetle				
	Flesh-flies	Family *Sarcophagidae*	105		
(7)	Flesh-fly parasite of Grasshoppers	*Sarcophaga variacauda* Coq	105	3, 4	17
	French Bug		89		
	(See Larger Sugar Beet Leaf-beetle or Alkali-beetle)				
	Gallworm		64–66		
	(See Root-knot Nematode or Gallworm)				
	Giant Thorn-headed Worm	*Echinorhynchus gigus*	50		
	Golden-eye		133		
	(See Lace-winged Fly)				
	Gordian Worm		107		
	(See Hair Worm)				

*Determined by S. A. Rohwer.

APPENDIX—Continued

Popular Name	Scientific Classification or Name	Text Reference	Illustration Reference	
		Page	Figure	Page
Grasshoppers	Family *Acrididae*	1, 3, 8, 29, 30, 31, 98–109, 130	8 to 15	17
			1	19
			16	106
			19	109
See: Rocky Mountain Locust				
Two-lined Hopper				
Differential Hopper				
Red-legged Locust				
California Devastating Locust				
Lesser Migratory Locus				
Green Peach-aphis	*Myzus persicae* Sulz	116, 117, 118	2, 9, 10	25
Ground Beetle	Family *Carabidae*	43, 54, 81, 105, 108, 130	1, 2, 3, 20, 21, 22	27
			17	107
See: Bombardier-beetle				
Egg-eating Amara				
Fiery Hunter				
A Species of Ground Beetle common in Beet Fields		130	3	27
Grub, White				
(See White Grub)				
Hair Snake (See Hair Worm)		107		
Hair Worm	Family *Gordiidae*, Genus *Gordius*	107, 108	16	17
			17	107
			18	108
Harvestmen	Order *Phalangidae*	106		
Ichneumon-fly	Family *Ichneumonidae*	3, 43, 83, 135, 136		
(8) Ichneumon-fly parasite of Alfalfa Looper	*Iloplectis atrocoxalis* Cress.*	83, 136	9, 10	21
(9) Ichneumon-fly parasite of Sugar Beet Webworm	*Cremnops vulgaris*	77, 137	7	19
(10) Ichneumon-fly parasite of Western Army Cutworm	*Amblyteles longula* Cress.†	43, 136	5	11
June-bug	Family *Scarabaeidae*	48, 50		
(See White Grub)				

*Determined by S. A. Rohwer. †Determined by A. B. Gahan.

APPENDIX—Continued

	Popular Name	Scientific Classification or Name	Text Reference	Illustration Reference	
			Page	Figure	Page
	Lace-winged Fly	Family *Chrysopidae*	3, 116, 133, 134	16, 17, 18, 19	27
	Lady-beetle or Lady-bug	Family *Coccinellidae*	59, 115, 132	14, 15, 23, 24	27
(11)	Lady-beetle enemy of Sugar Beet Root-lice*	*Symnus collaris* Melch	59	10, 15 14	13 23
	Larger Sugar Beet Leaf-beetle or Alkali-beetle	*Monoxia puncticolis* Say	7, 8, 89, 90, 92, 133	1, 2, 3, 4, 5	23
	Leaf-beetles		88, 89, 91, 96		
	See: Blister-beetles				
	Flea-beetles				
	Banded Flea-beetle				
	Potato Flea-beetle				
	Three-spotted Flea-beetle				
	Larger Sugar Beet Leaf-beetle or Alkali-beetle				
	Spinach Carrion-beetle				
	Western Beet Leaf-beetle				
	Leaf-eating Caterpillars				
	(See Caterpillars, Leaf-eating)				
	Leaf-hoppers	Family *Jassidae*	7, 111, 123–128		
	See: Clover Leaf-hopper				
	Rose Leaf-hopper				
	Sugar Beet Leaf-hopper				
	Leaf-miners		1, 3, 67, 110, 111		
	(See Beet or Spinach Leaf-miner)				
	Lesser Migratory Locust	*Melanoplus atlanis* Riley	100		
	Locust Mite	*Trombidium locustarum* Riley	106, 107	1, 2, 17, 18	19
	Locust, Red-legged				
	(See Red-legged Locust)				
	Locust, Rocky Mountain				
	(See Rocky Mountain Locust)				
	Masked Bedbug Hunter	*Opsicoetus personatus*	133		
	May-beetle	Family *Scarabaeidae*	48, 51		
	(See White Grub)				

*Determined by C. P. Gillette.

APPENDIX—Continued

	Popular Name	Scientific Classification or Name	Text Reference	Illustration Reference	
			Page	Figure	Page
	Mealy-bug	Family *Coccidae*	134		
	Mites	Order *Acarina*	29, 106, 134		
	Mud-dauber	Family *Eumenidae*	135	29	135
	Nematodes				
	See: Root-knot Nematode or Gallworm				
	Sugar Beet Nematode				
	Owlet-moth	Family *Noctuidae*	38		
(12)	Pale Western Cutworm	*Porosagrotis orthogonia* Morr.*	41, 45, 46, 47	9, 10, 11, 12	11
	Pictured Soldier-bug	*Perillus claudus* Say	133	8, 9, 10, 11, 12, 13	27
	Plant-lice (or Aphids)	Family *Aphididae*	3, 7, 29, 30, 111–116, 132 134, 137	20, 21	112
	Potato-beetle, Colorado				
	(See Colorado Potato-beetle)				
	Potato Flea-beetle	*Epitrix cucumeris* Harris	93	5	17
	Psyllids	Family *Psyllidae*	134		
	Red-legged Locust	*Melanoplus femur-rubrum* De Geer	100	14, 15	17
	Robber-fly	Family *Asilidae*	78	12	21
	Rocky Mountain Locust	*Melanoplus spretus* Uhler	98–100, 101, 106, 107		
	Root-knot Nematode or Gallworm	*Heterodera radicicola* (Greef; Müller)	3, 6, 64–66	8	64
	Root-louse, Corn				
	(See Corn Root-louse)				
	Root-louse, Sugar Beet				
	(See Sugar Beet Root-louse)				
	Rose Leaf-hopper	*Typhlocyba rosae* L.	123		
	Sacred Beetle of Egypt	*Ateuchus sacer*, Family *Scarabaeidae*	48, 49		
	Skip-jack	Family *Elateridae*	52	16, 17	11
	(See Wireworm)				
	Snapping-beetle	Family *Elateridae*	52	16, 17	11
	(See Wireworm)	Species *Alaus oculatus*		5	52
	Solitary Wasp	Family *Eumenidae*	77, 78, 135		
(13)	Solitary Wasp enemy of Sugar Beet Webworm	*Odynerus annulatus* Say†	77, 78, 135	15 14	21 78

*Determined by Dr. Dyer. †Determined by S. A. Rohwer.

APPENDIX—Continued

Popular Name	Scientific Classification or Name	Text Reference Page	Illustration Reference Figure	Illustration Reference Page
Spider-wasp	Family *Pompilidae*	134		
Spinach Carrion-beetle	*Silpha bituberosa* Lec.	7, 94, 95	10, 11	23
Spinach Leaf-miner		110, 111		
(See Beet or Spinach Leaf-miner)				
Stink-bug	Family *Pentatomidae*	119, 133		
Stink-bug enemy of Potato-beetle	*Perillus claudus* Say	133	8, 9, 10, 11, 12, 13	27
Sugar Beet Leaf-hopper	*Eutettix tenella* Baker	8, 123–126	5, 6, 7	25
			7	60
			25	124
			26	125
Sugar Beet Nematode	*Heterodera schachtii* Schmidt	3, 6, 31, 38, 59–64, 65	8, 9, 10	15
			6	60
Sugar Beet Root-louse	*Pemphigus betae* Doane	3, 6, 38, 55–59, 111, 113	1 to 9, 11 to 13, 16 to 18	13
			22	113
Sugar Beet Webworm	*Loxostege sticticolis* L.	7, 67–78, 135, 137	3, 4, 5, 6, 8, 9, 10, 11	19
		9		69
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Sugar Beet Wireworm	*Limonius californicus* Mannh.	53		
Syrphus-fly	Family *Syrphidae*	59, 116		
(14) Syrphus-fly enemy of Sugar Beet Root-louse	*Syrphus paulxillus* Will.*	59	13	21
Tachina-fly	Family *Tachinidae*	77, 85, 87		
(15) Tachina-fly parasite of Alfalfa Webworm	*Phryxe* Sp.†	85	11	21
(16) Tachina-fly parasite of Sugar Beet Webworm	*Meteorus loxostegei* Vier.‡	77	13	19
Tarnished Plant-bug	*Lygus pratensis* Linn.	6, 122, 123		
Thread-waisted Wasp	Family *Sphecidae*	134, 135	29	135
Three-spotted Flea-beetle	*Disonycha triangularis* Say	93	6	17
Ticks	Order *Acarina*	29, 106		

*Determined by C. P. Gillette. †Determined by C. H. T. Townsend. ‡Determined by A. B. Gahan.

Popular Name	Scientific Classification or Name	Text Reference	Illustration Reference	
		Page	Figure	Page
Tiger-beetle	Family *Cincindelidae*	76, 131, 132	5, 6, 7	27
			13	76
			27, 28	131
	Species *Cincindela vulgaris* Say		6	27
	Species *Cincindela purpurea* Oliv		7	27
True Army Worm	(*Heliophila*) *Cirphis unipuncta* Haw	78–81	21, 22, 24, 25	11
True Bugs	Order *Hemiptera*, Suborder *Heteroptera*	3, 29, 30, 59, 111, 119, 122, 132, 133		
A species of True Bug which preys upon Sugar Beet Root-lice	*Authocoris melanocerus*	59	14	13
Tumble-bug	Family *Scarabaeidae*	48		
(See White Grubs)				
Two-lined Hopper	*Melanoplus bivittatus* Say	100	9, 10, 11	17
Two-winged Flies	Order *Diptera*	29, 30, 111, 121		
Variegated Cutworm	*Peridroma margaritosa* Haw	8, 47, 48	7, 15	23
Virginia Tiger-moth	*Diacrisia virginica* Fab	87		
Wasps	Order *Hymenoptera*	3, 29, 30, 44, 45, 134, 135		
See: Digger-wasp				
Solitary Wasp				
Spider Wasp				
Thread-waisted Wasp				
Webworms:				
See: Alfalfa Webworm				
Sugar Beet Webworm				
Western Army Cutworm	*Chorizagrotis auxiliaris* Grote	8, 41–45, 46, 47, 88, 136	1, 2, 3, 4,	11
			4	42
Western Beet Leaf-beetle	*Monoxia consputa* Lec	90, 91	6	23
White Grub	Family *Scarabaeidae*	3, 5, 31, 38, 48–52, 53, 54, 97, 134	19, 20, 23	11
Wireworm	Family *Elateridae*	3, 5, 31, 38, 50, 52–54	13, 14, 15, 16, 17, 18	11
Yellow-bear Caterpillar	*Diacrisia virginica* Fab	8, 86, 87	15, 16	19
Yellow Jacket	Genus *Vespa*, Family *Vespidae*	135		
Zebra Caterpillar	*Mamestra picta* Harr	8, 87, 88	11	15

APPENDIX—Concluded

Popular Name	Scientific Classification or Name	Text Reference	Illustration Reference	
		Page	Figure	Page
	B—PLANTS			
Ash, White	*Fraxinus americana*	112	21	112
Burning Bush	*Euonymus* species	118	24	118
Common Mallow	*Malva rotundifolia* L.	125		
Cottonwood, Narrow-leaf	*Populus angustifolia* James	57, 58, 113	22	113
Fanweed	*Thlaspi arvense* L.	6		
Golden-glow	*Rudbeckia* species	115		
Goldenrod	*Solidago* species	98, 133		
Green-berried Nightshade	*Solanum triflorum* Nutt.	94		
Horse Bean	*Vicia faba*, or *Faba vulgaris*	119		
Lamb's-quarters	*Chenopodium album* L.	69,71,75,86,93,94,111,128		
Love-grass	*Eragrostis major* Host	121		
Lupine, Yellow		63		
Macrosiphum		115		
Mallow, Common	*Malva rotundifolia*	125		
Narrow-leaf Cottonwood	*Populus angustifolia* James	57, 58, 113	22	113
Pennycress	*Thlaspi arvense* L.	121		
Peppergrass	*Lepidium* species	119, 121		
Pigweed	*Chenopodium album*	111		
Poverty-weed	*Franceria tomentosa*	91, 92		
Rabbit Brush	*Chrysothamnus* species	46		
Russian Thistle	*Salsola tragus* L.	69, 71, 75, 86, 90, 93, 98		
Saltbush	*Atriplex argentea*	90		
Shepherds-purse	*Bursa bursa-pastoris* Moench	6, 119, 120, 121		
Spindle Tree	*Euonymus* species	118	24	118
Stink-grass	*Eragrostis major* Host	121		
Strawberry Bush	*Euonymus* species	118	24	118
Waahoo (or Wahoo)	*Euonymus* species	118	24	118
White Ash	*Fraxinus americana*	112	21	112
White Pigweed	*Chenopodium album*	111		
Yellow Lupine		63		

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